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THE CHEMISTRY

...OF...

PLANT AND ANIMAL LIFE

...BY...

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PREFACE

THIS book is the outgrowth of instruction in chemistry given in the School of Agriculture of the University of Minnesota since 1891. At first the classes were small and individual work with blackboard exercises and references to the literature in the school library was possible. With increased numbers of students, mimeographed notes were supplied until finally the size of the classes, and the volume of the notes have necessitated their publication in book form. The work was first given, in 1891, to a class of seven students, while twelve years later they numbered nearly one hundred fifty.

The class of students to whom this instruction has been given have been mostly earnest workers who attended school largely from personal choice and who desired to make as much progress as possible. Numerous questions have been asked by them relating to the application of chemistry to farm and every-day life, and for a number of years the author kept a question box in which were placed the more important questions asked in class, and the difficulties experienced in the laboratory work, and in developing the work from year to year these questions and difficulties have been considered.

This work was originally outlined as Agricultural Chemistry, but as special features have been developed and published, as the "Chemistry of Soils and Fertilizers," and "The Chemistry of Dairying," this part of the subject has gradually developed into "The Chemistry of Plant and Animal Life," and includes the composition of plant and animal bodies, the chemistry of the plant and of its food and growth, the chemistry of human foods and animal nutrition, the digestibility and value of foods and the laws governing their economic use. A few topics of an industrial nature but closely related to plant and animal life are also included.

Before taking up the special parts relating to the chemistry of plant and animal bodies, the elements and simpler compounds present in plants and animals, together with the laws governing their combinations, are considered so as to prepare the way for a more intelligent study of the subject. Laboratory practice forms an important feature, and questions are asked in connection with each experiment. Many of the experiments and problems are given to illustrate some special feature of the composition of plant and animal bodies. The illustrations, with the exception of a few as noted, are original.

With mature earnest students, six months with a classroom or laboratory exercise each day are required to complete this work, although a longer time could advantageously be given to the subject. It has been the aim throughout to present the topics in such a way that they would be easily understood and to develop the reasoning powers of the student so that he would be able to make the best use of his chemistry in every-day life affairs.

HARRY SNYDER.

March 1, 1903.

INTRODUCTION

PLANT life and animal life are dependent upon the changes which are continually taking place in nature. The laws of nature, as far as they are known, are set forth in the various sciences among which chemistry occupies a prominent place. In every-day life affairs, chemistry takes an important part because it is the science which treats of the composition and uses of substances found in nature. Plant and animal foods which are essential for life are simply mechanical mixtures of various forms of matter which are constantly undergoing changes and exemplifying the laws of chemistry. In agriculture, chemistry takes an important part, the term Agricultural Chemistry being applied to that branch of the science which concerns itself with the practical application of the laws of chemistry to the science of agriculture.

In the cultivation of the soil, production of crops, feeding of animals, manufacture of farm products, preparation and use of human foods, and in all life processes numerous chemical changes take place, and it is in part the province of chemistry to investigate these changes so as to assist nature in rendering the plant food of the soil more available, and to produce crops of the highest nutritive value, as well as to indicate ways in which the best possible use can be made of farm products in the feeding of animals and men. Before these subjects can be considered in an intelligent way, a fundamental knowledge must be obtained of some of the basic principles and laws of chemistry, since they are as essential to future work along special lines, as is a good foundation to a building, or a scaffold during its construction. In the household, arts, industries, and professions, constant use is made of products formed from the soil, air and water. In order to understand more perfectly the nature of the substances dealt with so as to make the most intelligent use of them, it is necessary to have a practical knowledge of some of the laws of chemistry and of the properties of the elements and compounds which enter into the composition of plant and animal bodies.

To the student who begins the study of chemistry, it is imperative that the first part of the subject be thoroughly mastered. Chemistry is different in its nature from many subjects. It cannot be studied in disconnected parts but must be undertaken systematically. It cannot be absorbed by listening to lectures, but must be studied. If the first part of the work is neglected, a failure is almost inevitable. If particular attention is given to the elements and their combinations, to the composition of matter, to laboratory manipulations, and to the classification of the elements, and if the experiments are performed regularly, the student experiences a keen enjoyment in the subject, the work ceases to be drudgery and becomes a pleasure.

The student should make an effort to learn how to study; the memorizing of chemical formulas and equations is not studying chemistry; he should master the principles governing the combination of elements and then the memorizing of chemical formulas becomes unnecessary. In the preparation of the lessons, there are a number of reference books which should be consulted occasionally. For example, if difficulty is experienced with the subject of valence and radicals, the interesting chapter upon these topics in Ellen H. Richards' "Chemistry of Cooking and Cleaning" should be read. Remsen's "Chemistry," Hart's "Chemistry for Beginners," Storer and Lindsay's "Elementary Manual of Chemistry," as well as many others, will be found valuable. In studying the parts relating to foods, crops, and animal feeding, Henry's "Feeds and Feeding," Jordan's "Feeding of Farm Animals," Armsby's "The Principles of Animal Nutrition," "Johnson's How Crops Grow," and "How Crops Feed," and the bulletins of the U. S. Department of Agriculture and of the several stations should be available. The student should early acquire the habit of consulting other works, as many topics are presented more clearly in one work than in another.

He who studies chemistry from a professional point of view, as medical chemistry, pharmaceutical chemistry, or agricultural chemistry, should remember that because of the limited time for the subject in professional schools, he is receiving at the best only a very abridged course in the science. Hence the necessity of supplementing the work by collateral reading and study; otherwise he comes into contact with only one phase of the subject, and while he receives a technical education, he may obtain only a limited and narrow view of the science of chemistry.

In the study of the "Chemistry of Plant and Animal Life," it is the aim to bring the student into close contact with nature which is one of the requisites for perfect agriculture. Although not all of the laws relating to the chemistry of plant and animal life have been discovered, many of those relating to soils and foods, particularly human foods, are known and can be applied to every-day life affairs.

CONTENTS

INTRODUCTION

Chemistry in its relation to plant and animal life; Relation to other sciences; How to study chemistry; Reference books and how to use them; Importance of chemistry. Pages v–viii.

CHAPTER I

Composition of Matter.—Physical and chemical changes; Indestructibility of matter; Molecules; Atoms; Elements; Compounds; Chemical affinity; Mechanical mixtures; Chemical analysis and synthesis; Summary. Pages 1–7.

CHAPTER II

Properties of Elements and Compounds.—Physical properties; Chemical properties; Symbols of the elements; Formulas of compounds; Atomic weights; Molecular weights; Law of definite proportion; Valence; Combination of elements; Problems on combination of elements; Experiments and questions. Pages 8–18.

CHAPTER III

Laboratory Manipulation.—Importance of laboratory practice; Names and uses of apparatus; Cutting glass tubing; Bending glass tubing; Perforating corks; Weighing; Measuring liquids; Obtaining reagents from bottles; Filtering; Laboratory note-book; Breakage of apparatus; Care of sinks and plumbing; How to accomplish the best results in the laboratory. Pages 19–30.

CHAPTER IV

Oxygen.—Occurrence; Preparation; Properties; Importance; Problems, experiments, and questions; Part taken in plant and animal life. Pages 31–36.

CHAPTER V

Hydrogen.—Occurrence; Preparation; Properties; Importance;

Problems, experiments, and questions ; Part taken in plant and animal life. Pages 37–41.

CHAPTER VI

Nitrogen.—Occurrence ; Preparation ; Properties ; Importance ; Problems, experiments, and questions ; Part taken in plant and animal life. Pages 42–45.

CHAPTER VII

Carbon.—Occurrence ; Preparation ; Properties ; Coal ; Allotropism ; A reducing agent ; Combustion ; Spontaneous Combustion ; A decolorizer and deodorizer ; Products of combustion ; Compounds of carbon ; Importance ; Experiments and questions ; Part taken in plant and animal life. Pages 46–55.

CHAPTER VIII

Water.—Chemical composition ; Physical properties ; Water of crystallization ; Natural waters ; Impurities and relation to diseases ; Location of wells ; Mineral impurities ; Contamination of drinking water : Methods of improving drinking waters ; Water filters ; Experiments and questions. Pages 56–65.

CHAPTER IX

Air.—A mechanical mixture ; Carbon dioxid ; Ammonium compounds ; Moisture ; Ozone and hydrogen peroxid ; Argon and helium ; Organic impurities and ventilation of rooms ; Air, a source of plant food ; Sources of contamination of air; Experiments and questions; Importance of air in plant and animal life. Pages 66–71.

CHAPTER X

Acids, Bases, Salts and Neutralization.—Classification of elements; Acids; Bases; Salts; Radicals; Naming of acids; Naming of bases ; Naming of Salts ; Double salts ; Acid salts ; Basicity of acids ; Two series of salts. Pages 72–79.

CHAPTER XI

Hydrochloric Acid, Chlorin and Chlorids.—Occurrence ; Preparation ; Properties ; Preparation of chlorin ; Properties ; The chlorin

group of elements ; Chlorids ; Problems ; Experiments and questions. Pages 80–85.

CHAPTER XII

Nitric Acid and Nitrogen Compounds.—Occurrence ; Preparation ; Properties ; Importance ; Ammonia ; Occurrence ; Preparation ; Properties ; Uses ; Oxids of nitrogen ; Anhydrids ; Law of multiple proportion ; Importance of the nitrogen compounds ; Problems ; Experiments and questions. Pages 86–92.

CHAPTER XIII

Phosphorus and Its Compounds.—Occurrence ; Preparation ; Properties ; Oxids ; Phosphoric acid and phosphates ; Compounds of phosphorus ; Importance of phosphorus and its compounds ; Problems ; Experiments and questions. Pages 93–96.

CHAPTER XIV

Sulfur and Its Compounds.—Occurrence ; Preparation ; Properties ; Uses ; Sulfur dioxid ; Sulfuric acid ; Properties of H_2SO_4 ; Sulfates ; Sulfids ; Problems ; Experiments and questions. Pages 97–102.

CHAPTER XV

Silicon and Its Compounds.—Occurrence ; Preparation and properties ; Silicic acid ; Dialysis ; Silicates ; Importance of compounds of silicon ; Problems ; Experiments and questions. Pages 103–106.

CHAPTER XVI

Oxids of Carbon, Carbonates, and Carbon Compounds.—Carbon dioxid ; Carbon monoxid ; Marsh gas ; Hydrocarbons ; Petroleum ; Use of gasoline ; Illuminating gas ; Mineral oils ; Oil of turpentine ; Creosote ; Benzene or benzol ; Aliphatic and aromatic series of compounds ; Carbon disulfid ; Cyanids ; Carbids ; Fuels ; Caloric value of fuels ; Foods ; Production of organic compounds in plants ; Decay of organic compounds ; Experiments. Pages 107–119.

CHAPTER XVII

Writing Equations.—Importance ; Common errors in writing

equations; Impossible reactions; A knowledge of reacting compounds and products necessary; Equations for class room work. Pages 120–126.

CHAPTER XVIII

Potassium, Sodium, and Their Compounds.—Occurrence of potassium; Potassium hydroxid; Potassium nitrate; Potassium carbonate; Potassium chlorate: Potassium sulfate; Miscellaneous potassium salts; Occurrence of sodium; Sodium chlorid; Sodium nitrate; Sodium carbonate; Sodium hydroxid; Sodium phosphate; Miscellaneous sodium salts; Experiments. Pages 127–133.

CHAPTER XIX

Calcium, Magnesium, and Their Compounds.—Occurrence of calcium; Calcium carbonate; Calcium oxid; Calcium hydroxid; Calcium sulfate; Calcium chlorid; Bleaching-powder; Calcium phosphate; Mortar; Glass; Occurrence of magnesia; Magnesium salts; Experiments. Pages 134–139.

CHAPTER XX

Iron, Aluminum, and Their Compounds.—Occurrence of iron; Reduction of iron ores; Wrought iron; Steel; Rusting of iron; Iron compounds; Occurrence of aluminum; Alums; Pottery; Experiments. Pages 140–147.

CHAPTER XXI

Copper, Zinc, Lead, Tin, Arsenic, Mercury, Their Compounds and Alloys.—Commercial importance; Occurrence of copper and its metallurgy; Copper sulfate; Bordeaux mixture; Occurrence of zinc; Compounds of zinc; Galvanized iron; Occurrence of tin; Tin salts; Occurrence of lead; Oxids of lead; Lead carbonates; Lead salts; Uses of lead; Occurrence of arsenic; Paris green; Occurrence of mercury; Compounds of mercury; Experiments. Pages 148–154.

CHAPTER XXII

The Water-Content and Ash of Plants.—Water; Dry matter; Plant ash; Form of the ash elements; Amount of ash in plants; Importance of ash elements; Water culture; Sand culture; Occurrence and function of ash elements; Potassium; Sodium; Calcium;

Magnesium; Aluminum; Iron; Phosphorus; Sulfur; Silicon; Chlorin; Experiments; Problems. Pages 155–174.

CHAPTER XXIII

The Non-Nitrogenous Organic Compounds of Plants.—Organic matter; Non-nitrogenous and nitrogenous organic compounds; Classification of non-nitrogenous compounds; Carbohydrates; General characteristics; Cellulose; Occurrence; Physical properties; Chemical properties; Function and value; Food value; Amount of cellulose in plants; Crude fiber; Starch; Occurrence; Physical properties; Chemical properties; Function and value; Food value of starch; Amount of starch in plants; Dextrin; Structural formulas; Sugar; Classification of sugars; Occurrence of sucrose; Physical and chemical properties of sucrose; Milk-sugar; Maltose; Inversion of sucrose; Refining of sugar; Occurrence of dextrose; Chemical and physical properties; Levulose; Miscellaneous sugars; Optical properties of sugar; Sugar-beets; Food value of sugar; Gums; Pentosans; Pectin bodies; Nitrogen-free extract; Fats; Presence in plants; Physical properties; Chemical composition; Stearin; Palmitin; Olein; Miscellaneous fats; Saponification; Fatty acids; Waxes; Food value of fat; Amount of fat in plants and foods; Ether extract; Organic acids; Occurrence in plants; Tartaric acid; Malic acid; Succinic acid; Oxalic acid; Citric acid; Tannic acid; Function and food value of the organic acids; Essential oils; General properties; Occurrence; Chemical composition and properties; Essential oils of agricultural crops; Synthetic production of essential oils; Amount of essential oils in plants; Food value; Miscellaneous compounds in plants; Relationship of non-nitrogenous compounds of plants; Food value of the non-nitrogenous compounds; Experiments and questions. Pages 175–213.

CHAPTER XXIV

The Nitrogenous Organic Compounds of Plants.—Amount of nitrogenous matter in plants; Different terms applied to nitrogenous compounds; Complexity of composition; Classification of nitrogenous compounds; Proteids; General composition; Occurrence; Physical properties; Chemical properties; Classification

of proteids; Albumins; Globulins; Albuminates; Peptones and proteoses; Insoluble proteids; Food value of proteids; Amount in plants; Crude protein; Albuminoids; Composition; Nuclein; Gelatin; Mucin; Elastin; Food value of albuminoids; Amides and amines; Composition and properties; Formation and Occurrence in plants; Formation and occurrence of amides in animals; Food value; Amount in foods; Protein production and disintegration; Alkaloids; General composition; Plant alkaloids; Animal alkaloids; Food value and production; Mixed nitrogenous compounds; Lecithin; Nitrogenous glucosides; General relationship of the nitrogenous organic compounds of foods; Problems and experiments. Pages 214–234.

CHAPTER XXV

Chemistry of Plant Growth.—Seeds; Ash; Non-nitrogenous compounds; Nitrogenous compounds; Chemical changes during germination; Change of starch to soluble forms; Change of fats to starch; Change of insoluble proteids to soluble forms; Germination of seeds and digestion of food compared; Necessary conditions for germination; Heavy- and light-weight seeds; Movement of plant juices; Joint action of chemical and physical agents; Porosity of tissues; Osmosis; Chlorophyl and protoplasm; Chemical action in leaves of plants; Production of chlorophyl; Function; Production of organic matter; Experiments. Pages 235–246.

CHAPTER XXVI

Composition of Plants at Different Stages of Growth.—Composition and stage of growth; Assimilation of mineral food by the wheat plant; Assimilation of nitrogen by the wheat plant; Clover; Rapidity of growth; Flax; Rapidity of growth; Maize (corn); Importance; Roots; Stalks; Leaves; Tassel; Husks; Ripening period. Pages 247–256.

CHAPTER XXVII

Factors which Influence the Composition and Feeding Value of Crops.—Seed; Soil; Climate; Stage of maturity; Method of preparation as food; Improving the feeding value of forage crops. Pages 257–262.

CHAPTER XXVIII

Composition of Coarse Fodders.—Coarse fodders; Straw; Timothy hay, Hay, similar to timothy; Oat hay; Hay, similar to oat hay; Bromus inermis; Clover hay; Alfalfa and fodders similar to clover; Rape; Pasture grass; Corn fodder and stover; Silage. Pages 263–272.

CHAPTER XXIX

Wheat.—Structure of kernel; Proteids of wheat; Relation of nitrogen in wheat to nitrogen content of flour; Influence of fertilizers upon composition of wheat; Variations in composition of wheat; Storage in elevators; Grading; Composition of Unsound wheat; Composition of different varieties; American and foreign wheats; Wheat as animal food; As human food; Experiments and questions. Pages 273–288.

CHAPTER XXX

Maize (Indian Corn).—Structure of the kernel; Composition; Proteids; Nitrogenous and non-nitrogenous corn; Varieties; Grading; Corn products; Corn as a food; Experiments. Pages 289–295.

CHAPTER XXXI

Oats, Barley, Rye, Buckwheat, Rice, and Miscellaneous Seeds.—Structure of the oat kernel; Composition of oats; Oats as human and animal foods; Barley; Rye; Rice; Buckwheat; Millet seed; Peas and beans; Grading of grains; Experiments. Pages 296–302.

CHAPTER XXXII

Mill and By-Products.—Sources; Wheat by-products; Wheat bran; Wheat shorts; Wheat germ; Wheat screenings; Linseed meal; Cottonseed cake and meal; Oat feed; Gluten meal; Malt sprouts; Miscellaneous by-products; Inspection of feeding stuffs; Problems and experiments. Pages 303–311.

CHAPTER XXXIII

Roots, Tubers and Fruits.—General composition; Potatoes; Carrots; Parsnips; Mangel wurzels; Apples; Oranges; Lemons; Strawberries; Grapes; Olives; Dried fruits; Miscellaneous fruits; Food value. Pages 312–317.

CHAPTER XXXIV

Fermentation.—Insoluble ferments; Soluble ferments or enzymes; Aerobic and anaerobic ferments; Conditions necessary for fermentation; Soil ferments; Ferments in seeds; Ferments in bread-making; Ferment action and food digestion; Ferments and food preservation; Ferments in butter- and cheese-making; Disease-producing organisms; Beneficial organisms; Experiments. Pages 318–324.

CHAPTER XXXV

Chemistry of Digestion and Nutrition.—Digestion, a bio-chemical process; Digestion experiments; Caloric value of foods; Available energy of foods; Net energy of foods; Digestion of proteids; Digestion of the carbohydrates; Digestion of fats; Oxygen necessary for digestion; Factors influencing digestion; Mechanical condition; Combination of foods; Amount of food consumed; Palatability; Individuality; Miscellaneous factors influencing digestibility; Application of digestion coefficients; Digestible nutrients of foods; Problems. Pages 325–342.

CHAPTER XXXVI

Rational Feeding of Animals.—Balanced rations; A maintenance ration; Standard rations; Food requirements of animals; Food supply at different stages of growth; Food requirements of horses; Selection of food for horses; Foods required for beef production; Selection of foods for beef production; Food requirements of dairy cows; Selection of foods for dairy cows; Food requirements of swine; Food requirements of sheep; Calculation of balanced rations; Nutritive ratio; Comparative cost and value; Caloric value of rations; Sanitary conditions; Problems. Pages 344–365.

CHAPTER XXXVII

Composition of Animal Bodies.—Water and dry matter; Mineral matter; Fat; Nitrogenous matter; Proteids of meat; Albumin; Myosin; Syntonin; Hemoglobin; Insoluble Proteids; Peptones; Keratin; Albuminoids; Gelatin; Influence of food upon the composition of animal bodies; Composition of human body. Pages 366–373.

CHAPTER XXXVIII

Rational Feeding of Men.—Similarity of the principles of human and animal feeding; Dietary standards; Amount of food consumed per day; Calculating a balanced ration; Comparative cost and value of foods; Factors influencing digestibility; Requisites of a ration; Dietary studies; Chemical changes in the cooking of foods; Refuse and waste matters; Loss of nutrients in the preparation of foods; Mineral matter in a ration; Digestibility of foods; Digestibility of animal foods; Digestibility of vegetable foods; Relation of food to health; Tables of composition of human foods. Pages 374–398.

CHAPTER I

Composition of Matter

1. Physical and Chemical Changes.—All substances in nature are subject to change in form and composition. At a low temperature, water is converted into ice, and by the application of heat into steam. The three forms which water may assume—solid, liquid, and vapor—are simply different conditions in which it is capable of existing. When water is changed into steam or ice, nothing is either added to or taken from the particles of water, simply a change of form or a physical change takes place. When, however, an electric current is passed through water, the water is decomposed and two gases are produced. When such a change takes place, the water particles are subjected to a change in composition called a chemical change.

Limestone may be pulverized until it is as fine as wheat flour, and when examined with a microscope, each fragment is in all respects like the original piece, except in size. The crushing has resulted in simply dividing the limestone into a large number of particles. If, however, a piece of limestone is burned in a lime kiln, the product is entirely different in its properties from the original lime rock. When water is added to burned lime, it slakes, heat is generated, and steam is given off, while, when water is added to lime rock, no appreciable change takes place.

Changes which affect the form but not the composition of matter are known as physical changes. The production of steam from water, the freezing of water, the pulverizing of limestone, and similar changes which do not affect the composition of the material, are physical changes. When milk sours, fruits decay, or wood is burned, a different kind of change takes place. The smallest particles of which each of the materials is composed undergo a change in composition. The products formed are entirely different in character from the original substances. Such changes, which affect the identity or individuality of a material, are chemical changes.

2. **Physics** is the science which concerns itself with the changes which matter undergoes when the ultimate particles of a material retain their identity or individuality.

Animal and plant life are to a great extent dependent upon the physical changes which take place in the soil. Rain is the result of the action of physical agencies, as is also the pulverization of rocks and soils. In all manufacturing operations, and as the result of all kinds of manual labor, particularly upon the farm and in the workshop, physical changes are continually taking place.

3. **Chemistry** is the science which deals with the changes which matter undergoes when the ultimate particles lose their identity or individuality, and the products formed are entirely different from the original material.

Chemical changes are continually taking place. Plant growth and animal life are dependent largely upon the chemical as well as the physical changes which take place in the soil and in the air. Life processes are intimately associated with chemical changes. Chemical and physical changes are closely related ; a chemical change is often dependent upon a physical change, and a physical change is, in turn, often dependent upon a chemical change. A chemical change necessarily brings about a physical change. While the sciences of chemistry and physics are, to a certain extent, closely related, each nevertheless deals with a different phase of change which matter undergoes.

4. Indestructibility of Matter.—When either a chemical or physical change takes place, no matter is destroyed or produced. It is not possible either to create or destroy matter. This is known as the law of *indestructibility of matter*.

Whenever a chemical change takes place, the parts which make up the substance are rearranged in a new and different way, or they are combined with other materials. When wood is burned, it is changed into gaseous products and ashes ; the materials which composed the wood are not lost to nature, they simply assume a different form. The law of indestructibility of matter is one of the foundation principles of chemistry. It was believed, at one time, that metals, as copper, could be changed into gold, and other substances into different forms of matter. After many centuries of experimenting, it was found that this could not be done, and as the result, the law of indestructibility of matter was established.

5. Molecules.—It is possible, by mechanical means, as pulverizing, to reduce substances to a very fine state of division, and it is believed that if this division could be carried on by more refined methods, particles of matter could finally be obtained that would not be susceptible to farther division by purely physical methods. The smallest particle of a material that can exist and have all of the properties of the original material is called a molecule. Molecules, however, have never been separated as individuals. All forms of matter are composed of molecules. The proof that matter is composed of molecules is founded upon the laws of physics. The reasons for the acceptance of the molecular structure of matter cannot be profitably undertaken by the student of elementary chemistry, but properly form a very important part of advanced chemistry. The molecular structure of matter has been sufficiently well established to warrant the use of the term molecule by the student of elementary chemistry.

6. Atoms.—Whenever a chemical change takes place, the molecule is changed in composition. When an electric current is passed through water, the molecules of water are split up into simpler forms of matter. It is evident that the molecule is not the simplest form of matter, and that while the molecule is the smallest part of a substance, it is, in turn, made up of still smaller parts. These parts of matter which make up a molecule are called atoms. An atom is the smallest part of an elementary substance that can enter into combination to form a molecule. Atoms never exist in nature in a free or uncombined state, but unite to form molecules, and molecules in turn unite to form masses.

7. Elements.—The simplest forms of matter, as iron, copper and sulfur, from which it is impossible to extract or obtain simpler bodies, are called elements. The element is the simplest form in which matter can exist. All substances found in nature, as plant and animal bodies, rocks and soils, are composed of compounds which, in turn, are composed of elements. There are about 74 of these elementary forms of matter, although only about 18 take any important part directly or indirectly, as far as is known, in either plant or animal life processes. There are a few substances found in nature in elementary form, as iron, copper, gold, and sulfur, but most of the elements are in combination with others, forming compounds.

8. Compounds.—The substances found most abundantly in nature are compounds. A compound is formed by the chemical union of two or more elements. All compounds are made up of a definite amount, by weight, of separate elements which unite according to the laws of chemical combination. Water, for example, is a compound made up of two elements, hydrogen and oxygen. Sugar is a compound made up of three elements, hydrogen, carbon, and oxygen. When elements unite to form a compound, the elements lose their identity and the compound that is produced has entirely different and distinct chemical and physical properties from those of the elements of which it is composed.

9. Chemical Affinity.—The force or power which causes elements to combine to form compounds is called chemical affinity, and about this comparatively little is known. Whenever a compound is separated into its elements, chemical affinity or the force which holds the elements together is overcome. When elements combine to form compounds, it is because of the chemical affinity which the elements have for one another. Some elements have a stronger affinity for certain elements than for others.

10. Mechanical Mixtures.—When two or more substances mix, but fail to unite chemically, a mechanical mixture is obtained. When iron and sulfur are mixed, a mechanical mixture is the result, and the iron and the sulfur can, by purely physical methods, be separated. If, however, a mixture of iron and sulfur is heated, a chemical change takes place and it is impossible by physical methods, as by the use of a magnet or by solvents, to separate the iron from the sulfur. Compounds as well as elements may form mechanical mixtures.

11. Chemical Analysis and Synthesis.—Whenever a substance or a compound is separated into simpler compounds or elements, the process is called chemical analysis. When only the kinds of elements or simpler compounds are determined, the process is called qualitative analysis. If the percentage amounts are determined, it is called quantitative analysis. When elements or simpler compounds are united, the process is called synthesis. Synthesis and analysis are directly opposite processes. When substances are produced in the laboratory from simpler elements or compounds, it is called a synthetical process. Many useful compounds are produced synthetically.

12. Summary.—Substances may undergo either physical or chemical changes. A physical change does not destroy the identity or change the composition of the molecule. When a chemical change occurs, the atoms are combined in a different way and a new molecule is produced. The molecule is the smallest particle of matter that can exist and retain its identity or individuality.

Physics and chemistry are closely related sciences, but each deals with a different kind of change. Compounds are composed of molecules, and molecules of atoms. Atoms never exist free, but unite to form molecules. If a substance contains in its molecule only atoms of one kind, it is an element. If there are present atoms of more than one kind, it is a compound. Life processes are dependent largely upon the physical and chemical changes continually taking place in nature.

CHAPTER II

Properties of Elements and Compounds

13. Physical Properties.—In order to determine the value of any element or compound, a knowledge of its chemical and physical properties is necessary, and it is important that a clear idea be obtained as to what is meant by the terms chemical and physical properties of elements and compounds. Each element and compound has its own characteristic properties, which are different in a number of ways from those of other elements and compounds. The physical properties of a substance include:

1. Form or state of the material, as solid, liquid, or gas, which depends upon the temperature to which the substance is subjected. Many substances which are solid under ordinary conditions are, at higher temperatures, converted into liquids or vapors; and substances which are gases are in turn converted into liquids and solids at low temperature and under high pressure.

2. Weight or specific gravity. The weight or specific gravity of a material depends upon its molecular structure and upon the character of its individual molecules. Some of the elements and compounds have molecules of greater weight than have others. Liquids and gases are characterized as light or heavy according to their weight, compared with some material taken as the standard.

3. Color. The color of a compound is a physical property which is due to its chemical composition. Many of

the elements, as copper, silver, and gold, have characteristic colors. Some compounds owe their value entirely to their color, and are used for paints and dyes.

4. Odor and taste. The odor and taste of an element or compound are physical properties which are characteristic of the element or compound.

5. Electrical characteristics. Elements and compounds have definite electrical properties. They are either good or poor conductors of electricity, and offer a large or small amount of resistance to the passing of an electric current.

The way in which a substance responds to pressure, water, heat, and cold, depends upon its physical properties, and the physical properties in turn are modified by these agencies.

In the study of the elements and their compounds, the physical properties are also included because our knowledge of chemistry would be incomplete without considering the physical as well as the chemical properties of substances.

14. Chemical Properties.—In addition to the physical properties, each element and compound has definite chemical properties. This is because the molecules of the different elements are unlike in character and some of the elements and compounds are more readily affected by chemical agencies than are others. The molecules of compounds are made up of atoms of different kinds which impart different properties to the molecule. Copper, for example, has different chemical properties from gold. It will dissolve more readily in acids, tarnish in the air, and be acted upon more rapidly by other bodies than will gold. When iron is exposed to moisture and air it rusts, while aluminum is not readily affected by these agents. This is because iron and aluminum have different chemical properties. The chemical properties of a substance include the way in which it combines or produces chemical change when brought into contact with other elements or compounds. Some elements are characterized as chemically active or inactive. An active element is one that readily unites or combines with other elements, while an inactive or passive element is one that does not readily unite or combine. Some elements are active under certain conditions and with some of the elements, and inactive under other conditions and with other elements. The various elements require different conditions for producing chemical changes. In studying an element, the way in which it deports itself in producing chemical changes, the ability with which it combines with other elements, and the products which are formed as the result of the chemical changes, are some of the more important chemical properties considered.

The study of the chemical and physical properties of elements and their compounds is important in many ways, as the value of a substance depends entirely upon its properties. In the growing and cultivation of crops, the production, preparation, and the economic use of foods, the treatment of diseases, and in all manufacturing operations, as the smelting and refining of metals, the chemical and physical properties of the elements and their compounds are constantly made use of.

15. Symbols of the Elements.—In the study of chemistry, a characteristic system of notation is used. The name of an element, as oxygen, is not written in full, but a symbol or sign, denoting the element is employed. In the case of oxygen, the symbol is O. The symbol of an element is either the first letter of the name of the element, or the first with some characteristic letter, as Cl for chlorin. In some cases, the symbols are derived from the Latin names of the elements, as Fe (*Ferrum*) for iron. By use, the student soon becomes familiar with those symbols most commonly used.

Name.	Symbol.	Approximate atomic weight.	Valence.	Kind of element.
Aluminum........	Al	27	3	Base-forming
Antimony........	Sb	120.5	3, 5	......
Arsenic...........	As	75	3, 5	......
Barium...........	Ba	137.5	2	Base-forming
Bismuth..........	Bi	208	3, 5	......
Boron............	B	11	3	Acid-forming
Bromin...........	Br	80	1	Acid-forming
Calcium..........	Ca	40	2	Base-forming
Carbon...........	C	12	2, 4	Acid-forming
Chlorin..........	Cl	35.5	1	Acid-forming
Chromium........	Cr	52	4, 6	.....
Cobalt............	Co	59	2, 4	Base-forming
Copper...........	Cu	64	1, 2	Base-forming
Fluorin..........	F	19	1	Acid-forming
Gold.............	Au	197	3	Base-forming
Hydrogen........	H	1	1	......
Iodin....	I	127	1	Acid-forming
Iron.............	Fe	56	2, 3, 4	Base-forming
Lead.............	Pb	207	2, 4	Base-forming
Lithium..........	Li	7	1	Base-forming
Magnesium......	Mg	24	2	Base-forming
Manganese......	Mn	55	2, 4, 6	......
Mercury.........	Hg	200	1, 2	Base-forming

Name.	Symbol.	Approximate atomic weight.	Valence.	Kind of element.
Nickel	Ni	59	2, 4	Base-forming
Nitrogen	N	14	3, 5	Acid-forming
Oxygen	O	16	2	Acid-forming
Phosphorus	P	31	3, 5	Acid-forming
Platinum	Pt	195	4	Base-forming
Potassium	K	39	1	Base-forming
Silicon	Si	28	4	Acid-forming
Silver	Ag	108	1	Base-forming
Sodium	Na	23	1	Base-forming
Sulfur	S	32	2, 4	Acid-forming
Tin	Sn	119	2, 4	Base-forming
Zinc	Zn	65.5	2	Base-forming

16. Formulas of Compounds.—Since compounds are composed of elements, it is possible, by means of combination of symbols, to express the formula of a compound. The formula of a compound denotes the number and kinds of elements contained ; as, for water, the formula H_2O designates that the compound is composed of the two elements hydrogen and oxygen ; and for sugar, the formula $C_{12}H_{22}O_{11}$ denotes that the compound is made up of three elements, carbon, hydrogen, and oxygen. The formula always expresses the composition. In the formulas of compounds, figures are made use of, as 2 in H_2O, at the right of the H and partially below the line. In this formula, the 2 indicates that there are two atoms of H in the molecule. In the case of sugar, the figures used mean that in one molecule of sugar there are 12 atoms of C, 22 atoms of H, and 11 of O. The formula of a compound always represents one molecule of the compound unless some figure is placed to the left of the formula, as $2H_2O$. When placed in this position, the 2 designates that there are two molecules of water. Figures placed to the left of a formula and on the same line indicate the number of molecules, while figures to the right of the individual element represent the number of atoms of elements in each molecule. Hence the formula of a compound always designates the composition of the molecule, and the number and kind of atoms contained. Farther study of the formulas of compounds will show that additional facts, as composition by weight and volume, are also represented.

Exercise.—Name the elements, the number of molecules, and the number of atoms in each molecule in the following formulas: $NaCl$, $CaCl_2$, $2KCl$, $2K_2SO_4$, Al_2O_3, $5N_2O_5$, H_2SO_4, $NaOH$, HPO_3.

17. Atomic Weights.—An atom is the smallest part of an element present in a molecule. Atoms have definite properties, as weight. Hydrogen is the lightest material known. An atom of hydrogen, or the smallest part of hydrogen which can enter into chemical combination, is considered as having a weight of 1. The weight of the atom of any element is the number of times heavier that atom is than hydrogen, which is the standard. Oxygen, for example, has an atomic weight of 16, that is, an atom of oxygen weighs 16 times as much as an atom of hydrogen. Carbon has an atomic weight of 12, that is, an atom of carbon is 12 times as heavy as an atom of hydrogen. The way in which the atomic weights are obtained cannot, at this stage of the work, be profitably considered. Atomic weights are, however, obtained with a high degree of accuracy, and while the individual atoms and molecules are not susceptible, at the present time, to separation and weighing, the comparative weight, or the number of times heavier or lighter a definite number of molecules is than a similar number of molecules, in other forms of matter, can be accurately determined. While the absolute weight of a molecule or atom cannot be determined, its comparative weight can be. When chlorin, for example, combines with hydrogen, it is known that 35.45 times as much, by weight, of chlorin as of hydrogen has entered into combination. Hence the smallest part by weight of chlorin, which can combine, must weigh at least 35.45 times as much as the weight of the smallest particle of hydrogen which enters into combination. The atomic weights of the more common elements are given in the table on page 11.

18. Molecular Weights.—Since the molecules of compounds are composed of a definite number of atoms of elements, and each atom has a definite weight, it necessarily follows that a molecule has a definite weight. In the case of water, the formula H_2O represents one molecule of water, composed of two atoms of hydrogen and one of oxygen. As the atoms have definite weights, the weight of the molecule H_2O is the sum of the weights of the atoms in the molecule. Since hydrogen is taken as the standard and weighs 1, and there are two atoms of hydrogen, and one atom of oxygen weighing 16, the weight of the molecule will be $2 + 16$ or 18; that is, the molecule of water, H_2O, is 18 times heavier than one atom of hydrogen.

Exercise.—Compute the molecular weights of the compounds given in the exercise following the formulas of the compounds, Section 16.

19. Law of Definite Proportion.—A study of the combination of elements has shown that always when elements unite to form compounds, a definite weight of each element enters into the composition. This is known as the *law of definite proportion.* Chemical combination always takes place between definite weights of the elements, and a chemical compound always contains the same elements in exactly the same proportion by weight. The law of definite proportion is one of the foundation principles of modern chemistry, and has enabled the chemist to determine the composition of bodies. This law is founded upon facts independent of any hypothesis, and the accuracy of the law has been demonstrated by many investigators.

The theories relating to the composition of matter, particularly to atoms and molecules, are in harmony with this law of definite proportion. It is believed, since chemical combination takes place between definite masses of elements, it must also take place between the smallest particles of the substances. Since the smallest particles which enter into chemical composition are the atoms, chemical combination must take place between the atoms. The atoms all possess definite weights. Hence it can readily be understood why chemical combination takes place between definite weights of the elements. The next step in the study of the composition of matter is the way in which the elements combine, or the power of combination; this is known as valence.

20. Valence.—The valence of elements is the power which an atom of one element has of holding in chemical combination a definite number of atoms of other elements. Carbon, for example, has the power of uniting with or holding in chemical combination four hydrogen atoms ; carbon is said, therefore, to have a valence of 4. Elements which have power to hold only one atom of hydrogen in combination are called monovalent. Hydrogen is a monovalent element. Bivalent, trivalent, tetravalent, and pentavalent elements are those whose atoms have the power of uniting with 2, 3, 4, and 5 atoms of hydrogen or other monovalent elements. The valence of an element is spoken of as its combining power. Some of the elements have more than one valence. The valences of some of the more common elements are given on page 11.

21. Combination of Elements.—The combination of *two* elements to form compounds is always governed by the valence of the elements. When calcium and chlorin combine, the combination takes place in a definite way ; calcium has a valence of 2 ; chlorin has a valence of 1 ; hence, in order to make a chemical combination, it will take one atom of Ca, having a valence of 2, to combine with two atoms of Cl, each Cl atom having a valence of 1. $CaCl_2$ is the formula. Calcium could not combine with three atoms of chlorin, because compounds composed of *two* elements are always formed according to the valence of the elements. The valence of calcium, 2, limits the number of atoms of chlorin with which it can combine. If one of the elements, as oxygen, has a valence of 2, and the other element, as carbon, has a valence of 4, 2 atoms of oxygen, each atom having a valence of 2, will be required to combine with 1 atom of carbon, having a valence of 4. The formula is CO_2. In the formulas of compounds, the valences of the atoms uniting are always balanced or satisfied.

When two elements combine, and one of them has an odd valence, as phosphorus, which has a valence of 3, two atoms of the element with the odd valence are always required for combination. For example, two phosphorus atoms, each having a valence of 3, making a total valence of 6, require, in order to combine with O, whose valence is 2, three atoms of O, which make the valence of 6. The two atoms of phosphorus combine with the three atoms of oxygen, making a balanced compound, and the valences of the phosphorus and oxygen are satisfied. The compound is P_2O_3.

Combine according to the lowest valence, the following elements, and give the formulas of the compounds produced.

Zinc and oxygen
Calcium and oxygen
Tin and oxygen
Iron and oxygen
Potassium and oxygen
Silicon and oxygen
Sulfur and oxygen
Sodium and chlorin
Potassium and chlorin
Carbon and oxygen
Phosphorus and oxygen
Iron and sulfur
Potassium and sulfur
Manganese and sulfur
Phosphorus and hydrogen
Calcium and chlorin
Aluminum and oxygen
Phosphorus and oxygen

Problem 1.—How much hydrogen is required to combine with 20 grams of O to form H_2O? When hydrogen and oxygen unite to form water, the combination takes place according to valence, as follows: 2 atoms of H + 1 atom of O equal 1 molecule of water, or $2H + O = H_2O$. An atom of O weighs 16 times as much as an atom of H. Two atoms of H and 1 atom of O weigh 18 times as much as an atom of H. The molecular weight of water is 18. Sixteen of these 18 parts, by weight, are O, or 16/18 are oxygen, which is 88.88 per cent.; 2/18, or 11.12 per cent. being H. In the production of water, H and O always unite in this proportion. If, for example, 20 grams of O and 2 grams of H were brought together, only 16 grams of O would enter into chemical combination with the 2 grams of H, and 4 grams of O would be left uncombined. The amount of H required to combine with 20 grams of O would be obtained from the following proportion, —$2 : 16 :: x : 20$, or $x = 2.5$ grams of H.

Problem 2.—(1) Calculate the per cent. by weight of C and O in CO_2. (2) Calculate the per cent. of Fe and O in Fe_2O_3. (3) Calculate the per cent. of O in $KClO_3$.

CHAPTER III

Laboratory Manipulation

22. Importance of Laboratory Practice.—Laboratory practice is an essential part of the study of chemistry. Many of the important facts and laws of chemistry are capable of being demonstrated by the student, and the laboratory practice assists in developing more perfect ideas in regard to the composition of substances. The hand, the eye, the nose, and, to a less extent, the ear, are all called into use in the laboratory, and this results in a balanced education of the senses. Neatness is absolutely necessary for success in laboratory work. An experiment performed in a slovenly way, with dirty and poorly connected apparatus, and poor mechanical manipulation, fails to give the right impression or results.

When laboratory work is in progress it should receive the student's entire attention. The directions for the experiments should be carefully followed. The apparatus should always be put together as directed, and because of the danger of accident, the student should never take the risk of connecting apparatus in an original way, or of using for the experiment, materials other than those directed. The student should never attempt to experiment for himself in combining chemicals.

23. Names and Uses of Apparatus.—The various pieces of apparatus used in the experiments are shown in Plates I and II. Number 23 shows the common Bunsen burner, and at the right, the wing-top attachment, used in bending glass tubes. Number 24, Plate II, is an iron ring-stand with three rings, and No. 25 is a single clamp. The iron stand with rings is used for supporting apparatus, particularly the sand-bath (19) in which is a thin layer of sand. The evaporating dish (5), beaker (12), and flask (26) are all supported in the various experiments upon the sand-bath and iron ring-stand. In the cutting of glass tubes and the perforation of corks, the two files (1 and 2) are employed. Test-tube (13) is used extensively in the laboratory, and when heated it is supported in the test-tube clamp (18). This test-tube clamp is held in the hand. The test-tube is cleaned with the test-tube brush (17) and when not in use is placed in the test-tube rack (14). When solutions are filtered, the funnel (15) is used, and is supported in the wooden stand (21). Substances are pulverized or mixed in the mortar (16) which is supplied with a pestle. The various gases, as oxygen, hydrogen, and nitrogen, are collected in the small cylinder (10), and in some of the experiments, the large cylinder (11) is used. The iron spoon (8) is used for the ignition of substances. The crucible tongs (3) are for handling pieces of apparatus when hot. The other pieces of apparatus, Woulff bottle (7), water-bath (4), tripod (22), Hessian crucible (20), wide-mouthed bottle, (9), and the ground glass plate with a hole, are used in various ways in the different experiments. Glass rods, a thistle-tube, a pneumatic trough, and small squares of plain glass complete the set of apparatus. A few pieces, used only occasionally, are obtained from the instructor at the time the experiments are performed.

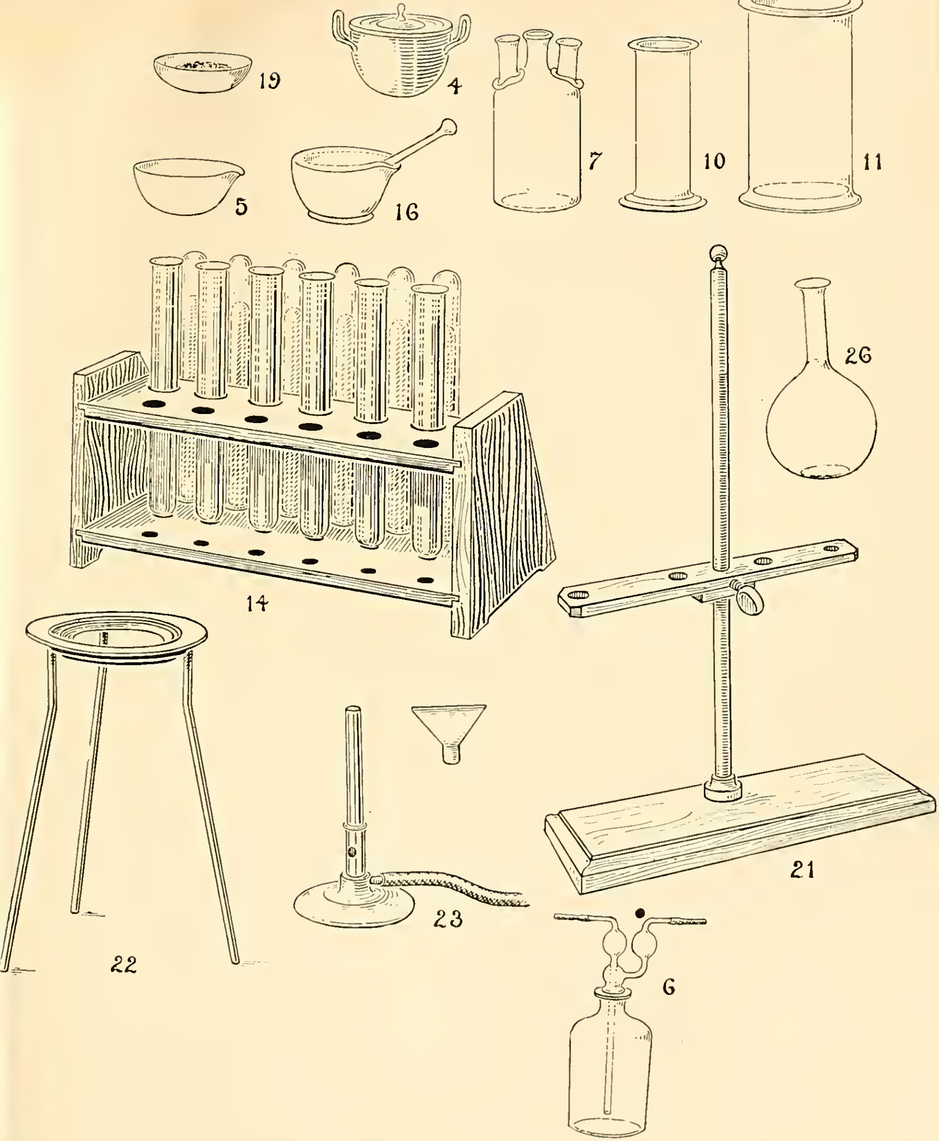
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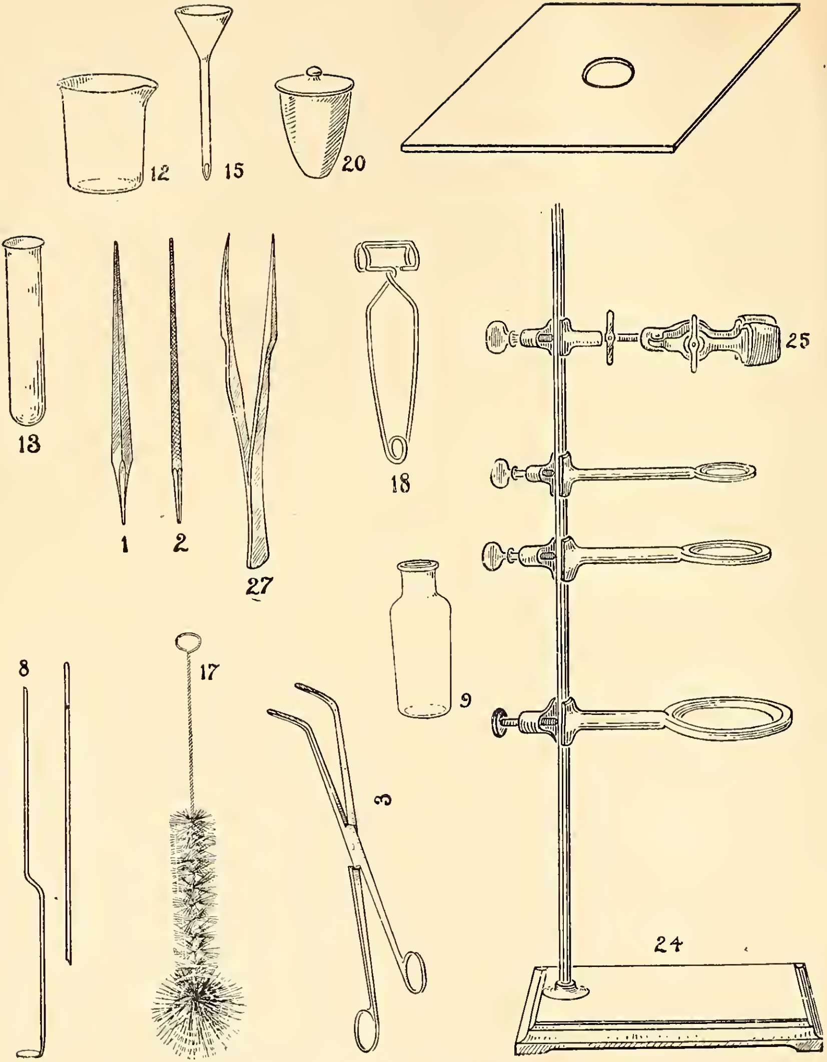
Plate I.—Apparatus used in experiments.


12
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1
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25
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17
3
24

PLATE II.—Apparatus used in experiments.

The student should take an inventory of his apparatus as soon as assigned a place in the laboratory. In case any of the pieces are broken or missing, the attention of the instructor should be called to them. Always, at the close of each day's work, the apparatus should be cleaned, placed in the desk, and the desk locked. The apparatus and desk should always be kept in a neat and orderly condition. Untidiness is a frequent cause of failure in laboratory work; neatness and careful attention to details are necessary to success.

24. Cutting Glass Tubing.—Lay the glass tube on the top of the desk or any flat surface. Draw a sharp three-cornered file across it two or three times, always on the same place at which it is to be broken, until a scratch is made through the annealed surface of the tubing. Take the tube in the hands with fingers and a thumb on each side of the scratch (see Fig. 1). The scratch should be nearly between and on the side opposite the thumbs. Pull the hands toward the body as if bending the tube,

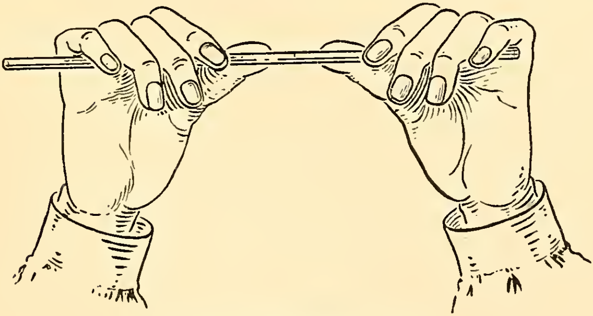


Fig. 1.—Breaking glass tubing.

and at the same time press outward with the thumbs. This causes a square break of the tube. The cut ends of the tubing should then be held in the outer portion of the flame until the rough edges are annealed.

25. Bending Glass Tubing.—Place the wing-top attachment on the burner. Hold the tube in the upper part of the flame as shown in the illustration (Fig. 2), and rotate so that all parts are heated alike. When the tubing becomes red and readily yields, it can be bent in almost any form desired, but if overheated it becomes too soft and collapses. It is always best to bend without removing from the flame. A little practice with pieces of old tubing will soon give the necessary experience. Avoid twisting or rapid bending of the tube. Make all bends on the same plane and aim to make well rounded joints as shown in Fig. 3.

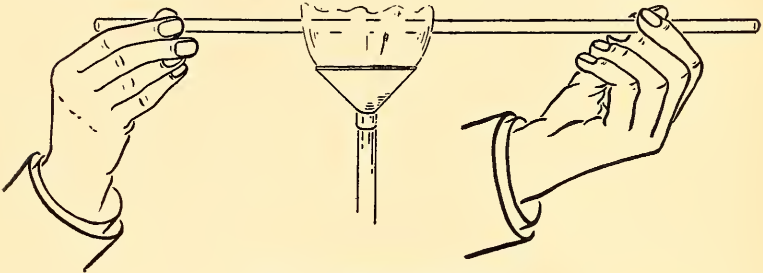


Fig. 2.—Bending glass tubing.

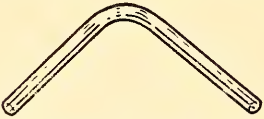


Fig. 3.—Bent tube.

26. Perforating Works.—Select a cork of suitable size for the test-tube or flask used. New corks should always be rolled in the cork press. With the small pointed end of the round file make a hole through the center of the cork, or a little to one side if directed to do so. This hole should be perpendicular to the surface of the cork. In making a hole, the cork should be held in the left hand, and the larger end should be placed against the edge of the desk. The file should be held in the right hand, and only enough pressure exerted to perforate the cork. By means of the round end of the file, the opening thus made is enlarged until the desired size is obtained. The hole should be a suggestion smaller than the tube it is to receive, which can be inserted easily if well annealed and wet. When inserting a tube in a cork, never push the tubing toward the palm of the hand, or use too much pressure; otherwise severe cuts may be received from breaking of the glass. Hold the cork in the left hand as shown in Fig. 4, and then with the right hand carefully insert the tube.

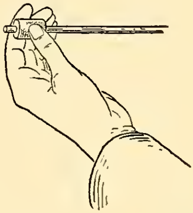


Fig. 4.—Inserting glass tube into cork.

27. Weighing.—In this work, the metric system of weights and measures is employed, and it is taken for granted that the student is familiar with the system; if he is not, he should review the subject as given in any ordinary arithmetic.

Note.—1 kilo = 2.2046 lbs. (avoirdupois).
1 oz. = 28.35 gms.
1 lb. = 453.59 gms.
1 liter = 1.05708 U. S. quart.
1 inch = 2.54 centimeters.
1 meter = 39.3808 inches.

The small balance used for weighing materials in these experiments is shown in Fig. 5. In case 5 grams of a material are to be weighed, prepare counterpoised papers, about 3 by 4 inches in size; that is, two pieces of paper of exactly the same size to be placed on opposite sides of the balance. If they do not weigh alike, remove small pieces of paper from the heavier pan, until the needle moves nearly as many divisions on one side of the scale as on the other. Then place, with the forceps, the 5-gram weight on the right-hand pan of the balance. Do not handle the weights with the fingers. By means of the scoop or spoon provided for the purpose, add to the paper in the left-hand pan of the balance, enough of the material that is to be weighed to counterpoise the 5-gram weight. If any of the substance has been spilled it should be cleaned up at once. *The weight should be replaced in the weight box and the forceps returned to their proper place.* If the weights are lost, a charge is made to cover the expense of their replacement. No substance except a piece of metal, as copper or lead, should ever be placed in direct contact with the balance pan. Liquids are never weighed, but always measured. Too much care and neatness cannot be exercised in weighing.

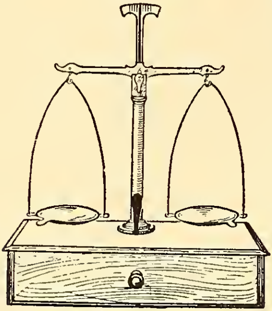


Fig. 5.—Balance.

28. Measuring Liquids.—For purposes of measuring, cylinders or graduates are employed (Fig. 6). A large test-tube, when filled with water, holds from 60 to 65 cc. Take a measuring cylinder or graduate (Fig. 6), measure out 5 cc. of water, and transfer to a large test-tube. Note the quantity, and then pour it out. Now draw water directly into the test-tube until you have approximately the same amount, then measure it. Repeat this operation until you can judge with a fair degree of accuracy the part of a test-tube filled by 5 cc. Then repeat the operation, using 10, 15, 20, and 25 cc. portions, until the eye has become reasonably familiar with these approximate and relative amounts; so that, if at any time a graduate is not at hand, the amounts can be estimated with the eye accurately enough for practical purposes.

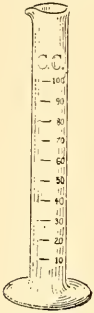


Fig. 6. Measuring cylinder.

29. Obtaining Reagents from Bottles.—Take the bottle from the shelf, remove the stopper, holding it between the first and second fingers of the right or left hand (Fig. 7). Hold the test-tube or vessel that is to receive the reagent in the other hand. Pour out the liquid slowly until the desired amount is obtained. Because of danger of contaminating the reagents, it is always better to pour the liquid slowly and secure the

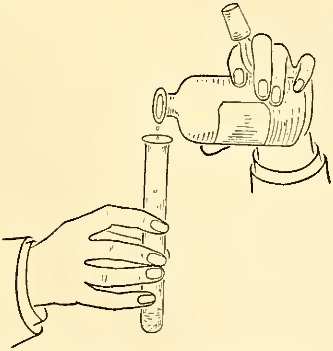


Fig. 7.—Pouring liquid from bottle.

right amount at first rather than to pour back from the receiving vessel. Replace the test-tube in the stand or receiver on the desk; then, before inserting the stopper, touch it to the neck of the bottle to catch the few drops on the edge, to prevent them from streaking down the sides of the bottle, and on to the shelf. *Be sure to replace the bottle on the shelf in its proper place.* Much annoyance and delay is caused by not returning the bottles to their proper places.

30. Filtering.—Place the funnel on the arm of the wooden stand. Fold a filter-paper so as to make a semicircle (see Figs. 8 and 9). Fold the paper again, forming a quadrant (Fig. 10). Then open it as shown in Fig. 11. Place the filter-paper in the funnel, using a little water to make it adhere to the sides. Place a beaker or cylinder under the funnel so as to collect the filtrate, or liquid which passes through the filter-paper (Fig. 12). Pour the material to be filtered into the filter-

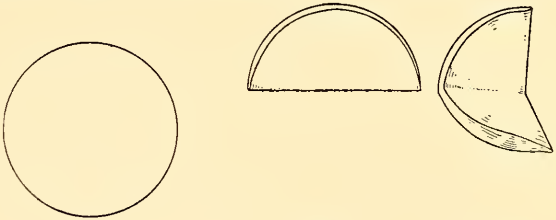


Fig. 8. Fig. 9. Fig. 10.

Folding filter-paper.

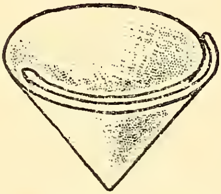


Fig. 11.—Folded filter-paper.

paper in the funnel. Do not fill the filter too full. An eighth of an inch or so should always be left between the surface of the liquid and the edge of the paper. The stem of the funnel should always be left against the side of the beaker or cylinder so as to avoid spattering. The material left on the filter-paper is called the precipitate or residue.

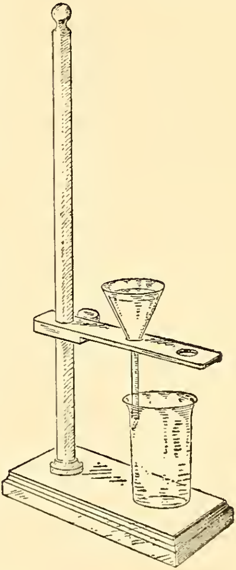


Fig. 12.—Filtering.

31. Laboratory Note-book.—Each student should keep a careful record of his laboratory work. The note-book should be complete and should represent the student's individual work. With each experiment a number of questions are asked, and the record of the experiment should embody the answers to these questions. Do not make short answers, as "yes" and "no," but make a complete statement, giving an intelligent answer to the question. Do not copy the laboratory directions into your note-book, but state *briefly and concisely*, (1) what the experiment is about, (2) the materials used, (3) the apparatus employed, (4) what you have observed in making the experiment, (5) the chemical and other changes that have taken place, and finally what the experiment proves. In writing up the note-book, it is not necessary to separate the topics, but all the questions should be numbered and answered in the order asked. Write out each experiment at the time it is performed ; and while the work is in progress, watch it and think about it. Do not leave or neglect an experiment. When the experiments are performed as called for from day to day, the labor of preparing the daily recitation is considerably lessened, and less effort is required to obtain a clear idea of the subject. The note-book should be kept in a neat and orderly way. Careful attention should be given to spelling, English, and punctuation. Always have the note-book in condition for examination if the books are called for without notice. The instructor will mark all errors, and the student should correct these errors. A note-book with errors that have been corrected, representing the student's individual work, is much to be preferred to a note-book, copied from some other student, and having but few errors. Each student has an individuality which always marks his work, and whenever copying of experiments is resorted to, it is detected by the instructor. The student who copies from some one else only cheats himself, and usually fails to pass his examinations.

32. Breaking of Apparatus.—If due care is taken in performing the experiments, there will be but little breakage of apparatus. In case an accident occurs, clean up the broken pieces at once and place them in the waste jar. If a liquid is spilled, wipe it up with a sponge, using plenty of water. If a strong acid is spilled, a little dilute ammonia should be used in the final washing. No combustible materials should be placed in the desk, and the student should throw burned matches and splinters into the receptacles provided for the purpose.

33. Care of Sinks and Plumbing.—Do not throw waste matter of any description, as paper, glass, matches, etc., into the sinks. Large waste jars, for such materials, are provided under every sink and elsewhere. Everything liable to clog the drains must be thrown into these jars. Liquids containing acids may be safely thrown into the sinks, provided a stream of water is kept running at the same time to dilute and wash out the acids. When acids are poured into the sinks, care should be taken to prevent spattering of the liquid, as severe burns are sometimes received when the liquid is not properly poured from the vessel. If directions are followed no accidents can occur. Do not fill the sinks too full. The water should never be allowed to come to within 2 inches of the top of the sinks. If the sinks overflow they cause much damage to the rooms below. Students who disregard the regulations in regard to plumbing and the use of sinks, will be held responsible and must pay for any damage caused by carelessness or negligence.

34. How to Accomplish the Best Results in the Laboratory.—In order to accomplish the best results, the student, while in the laboratory, should endeavor to use his time profitably and economically. He should obtain a clear idea of what he is to do, and then do it to the best of his ability. If the experiment is not a success, repeat the work. Never pass over an experiment that offers difficulties in performing. Much valuable time can be saved by a brief study of the day's work before going into the laboratory. While the work is in progress, the student should give it undivided attention, and make an effort to learn as much as possible from the experiments performed.

CHAPTER IV

Oxygen

35. Occurrence.—Oxygen is the most abundant element in nature. About one-fourth of the air, by weight, is free or uncombined oxygen. It enters into the composition of water, rocks, and minerals, and plant and animal bodies. Seven-eighths of water and one-half of the solid crust of the earth are oxygen in combination with other elements. Oxygen is also present in all animal and plant tissue, making up a large portion of the weight of these bodies.

36. Preparation.—Oxygen can be prepared from a number of materials, as oxid of mercury, oxid of iron, and potassium chlorate. When made in small amounts in the laboratory, it is usually prepared by heating potassium chlorate, a compound composed of the elements potassium, chlorin, and oxygen. The oxygen is separated by means of heat, the process being as follows:

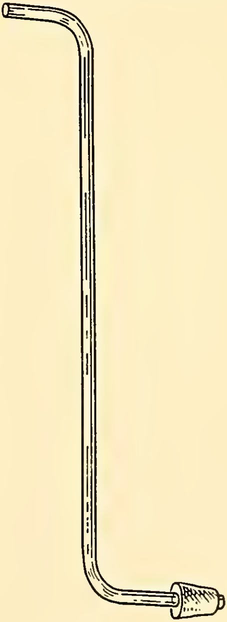


Fig. 13.—Delivery tube.

Experiment 1.—Anneal the end of a piece of glass tubing, 2 1/2 or 3 feet long. Make a bend nearly at right angles to the tube, about 3 inches from one end. Then make a second bend of 2 1/2 or 3 inches on the opposite end of the tube nearly at right angles, and in an opposite direction from the first bend (Fig. 13). Fit to the test-tube a cork, perforated as directed in Section 26, and insert the delivery tube. Fill the pneumatic trough nearly full of water, and place in it the free end of the delivery tube (Fig. 14). Weigh out 5 grams each of potassium chlorate ($KClO_3$) and manganese dioxid (MnO_2). Mix on a sheet of paper, and place the mixture in a test-tube. See that the test-tube is perfectly dry, both inside and out. Fill the cylinders with water, cover with glass plates and place them inverted on the shelf of the pneumatic trough. With a medium-sized flame, apply heat cautiously to the test-tube. The flame should be moved from time to time, and not allowed to strike just one part of the test-tube, otherwise the glass will melt, and the test-tube collapse. As soon as bubbles of gas are given off freely from the water, place the end of the delivery tube so that the gas is collected in one of the cylinders. When a cylinder is filled, cover it with one of the glass plates, while the mouth of the cylinder is still under water. It can then be placed upright upon the desk, and another cylinder filled with O. After collecting three or four cylinders of gas, remove the end of the delivery tube from the water, and then remove the flame. Do not remove the flame while the end of the delivery tube is under water, or a vacuum will be formed, and the water will rush back into the test-tube. Tests should be made with the O as follows :

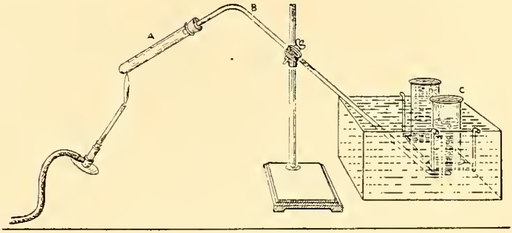


Fig. 14.—Preparation of oxygen. Pneumatic trough.

(1) Light a splinter and place it for a moment in one of the cylinders of oxygen (see Fig. 15) ; remove it ; extinguish the flame,

and while the splinter is still glowing, thrust it into the cylinder again. Observe the result in each case. (2) Put a small piece of sulfur, a little larger than a grain of wheat, into the iron or deflagration spoon; ignite in the flame, and then thrust into another cylinder of O. Observe the result. (3) Take a piece of bright fine iron wire or watch-spring, and make it into a spiral with a loop at one end. Warm the wire by holding it near the flame, then hold the loop for an instant in the flame and dip it into some sulfur which has been placed on a piece of paper. Hold again in the flame for a moment and then place at once in the third cylinder of O. In order to insure the success of this experiment, the wire should be very fine, free from rust, and held in the flame only long enough to start ignition, and then placed in the cylinder.

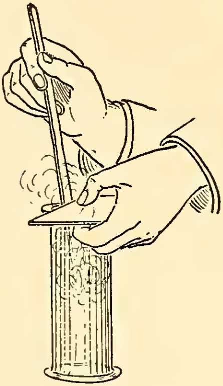


Fig. 15.—Testing oxygen with burning splinter.

Questions. (1) Where does the O in the cylinder come from? (2) What caused it to separate from the compound? (3) What is the appearance of O? (4) Compared with air, is it a light or heavy gas? (5) What caused the splinter to burn and to rekindle? (6) What product was formed when the splinter was burned? (7) What caused the sulfur to burn? (8) What product was formed when the S was burned? (9) Why do these materials burn differently in O than in air? (10) What caused the iron to burn, and what was formed? (11) Is O combustible? (12) Is O a supporter of combustion? (13) What compounds are always formed by the union of O with an element? (14) Give the properties and characteristics of O as observed from this experiment.

The oxygen in potassium chlorate is not held in firm chemical combination, and when the substance is heated, first a portion, and finally all of the oxygen is given off. The manganese dioxid is used because of its physical action upon the potassium chlorate, enabling the oxygen to be given off more easily. The change which takes place is expressed by the equation: $KClO_3 = KCl + 3O$. The products of the reaction are potassium chlorid and oxygen.

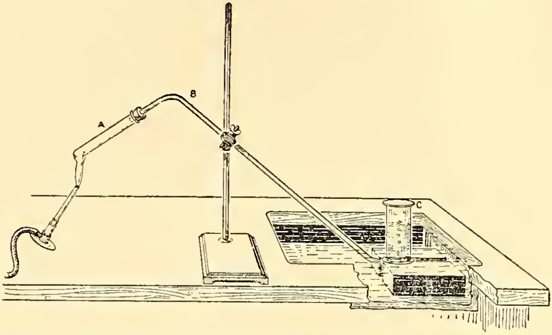


Fig. 16.—Preparation of oxygen, using sink in place of pneumatic trough.

The oxygen is collected in the cylinders, while the potassium chlorid remains with the manganese dioxid in the test-tube.

37. Properties of Oxygen.—Physically considered, oxygen is a colorless, odorless, and tasteless gas, about 16 times as heavy as hydrogen. It is slightly soluble in water, and, when subjected to a low temperature and a high pressure, it is liquefied. Chemically, oxygen unites with all common elements to form oxids. It is not combustible, but is a supporter of combustion. When the burning splinter was thrust into the cylinder of oxygen, the carbon and hydrogen of the wood united with the oxygen in the cylinder, forming carbon dioxid and water. When substances unite with oxygen they are oxidized, that is, oxygen is added to the material. An oxid is a compound of oxygen and any other element. When sulfur is burned, it unites with oxygen, forming sulfur dioxid, SO_2. Other elements, as phosphorus and iron also unite with oxygen, forming oxids. Different elements unite with oxygen at different temperatures. Phosphorus and sulfur combine with oxygen at a comparatively low temperature, while carbon and iron require a higher temperature. The sulfur and the splinter of wood burned more brilliantly in the oxygen than in the air because air is diluted with other gases and elements and is not pure oxygen. Oxygen is more active at a high than at a low temperature.

The oxidation of some of the elements and compounds results in the production of light and heat ; this is commonly called combustion. Oxygen forms stable compounds with many of the elements. It has such affinity for some elements, as aluminum and carbon, that it is separated from them with difficulty. With other elements it forms less stable compounds. When a substance contains oxygen, it does not necessarily follow that it is combustible, because it may be the product of combustion as carbon dioxid or sulfur dioxid. When an element, as oxygen, enters into chemical combination, it loses its identity or individuality as an element. The oxygen that is present in the minerals forming the crust of the earth, and in plant and animal tissues, is not free but combined with other elements.

38. Importance.—Oxygen takes an important part in life affairs, and is necessary to the existence of plant and animal bodies. The combustion of wood, coal, and other fuel is due to the oxygen of the air. The production of heat in the body is due to the oxidation of food, and many of the chemical changes which take place in the soil are dependent upon this element. Because of its wide distribution in nature, it is not given such economic consideration as are other elements, but it is one of the most important, and is as necessary for life as other food.

Problem 1.—How many pounds of oxygen are required to combine with 25 pounds of pure carbon? When carbon is burned, 1 part of C (called an atom) unites with 2 parts of O (2 atoms of O) to form the compound CO_2. This is expressed by the equation $C + 2O = CO_2$. The atomic or least combining weight of carbon is 12 and of O is 16; one part by weight of C weighing 12 unites with 2 parts by weight of O, each part weighing 16; or 12 parts by weight of C unite with 32 parts by weight of O. If the parts are designated pounds then 25 pounds of C will require proportionally as much O as do 12 pounds of C. This amount can be determined by a simple proportion.

$$\begin{array}{c} C : O :: C : O \\ 12 : 32 :: 25 : x. \end{array}$$

By solving this proportion, x, or the required amount of O to combine with 25 pounds of C, is found to be 66 2/3.

In the solving of chemical problems some of the most common errors are: (1) Failure to write properly the formulas of the compounds used, or the equation representing the chemical reaction that takes place. This error causes the wrong number of parts of elements or compounds to be taken in the proportion. (2) Failure to make proper use of the combining weights of the elements. (3) Failure to combine properly the weights so as to form a true proportion. It should be remembered that after the writing of the equation and weights, the problem becomes simply one of arithmetic.

Problem 2.—How many pounds of CO_2 are produced when 25 pounds of carbon are burned?

Problem 3.—How many pounds of carbon are necessary to combine with 25 pounds of O in forming CO_2?

CHAPTER V

Hydrogen

39. Occurrence.—Hydrogen is found in nature in combination with other elements, entering into the composition of water, animal and plant tissues, and some minerals. It is never found in a free state, except as given off in traces with volcanic gases. Hydrogen is also found in all acids and many other compounds.

40. Preparation.—In the laboratory, hydrogen is usually prepared by treating a metal with an acid, which contains hydrogen ; the metal replaces the hydrogen of the acid and the hydrogen is then liberated as a free gas. When zinc and hydrochloric acid are employed, the reaction which takes place is as follows : $Zn + 2HCl = ZnCl_2 + 2H$. Two molecules of hydrochloric acid are required in the reaction because zinc has a valence of 2, and whenever zinc enters into chemical combination, it must take the place of two monovalent atoms. The compound, $ZnCl_2$, zinc chlorid, contains one atom of zinc and two atoms of chlorin.

Experiment 2.—Arrange the apparatus as shown in Fig. 17. Use the small two-necked Woulff bottle, and in one of the necks insert a tight-fitting cork with a thistle tube. In the other neck insert a cork carrying a delivery tube. Place about 20 grams of zinc, Zn, and 25 cc. of water in the Woulff bottle. The thistle tube should pass below the surface of the water to prevent the escape of gas. Fill two or three cylinders with water for collecting the gas. The corks carrying the delivery tube and the thistle tube should fit tightly, otherwise the H is easily lost. When all is ready, add, through the thistle tube, about 15 cc. concentrated hydrochloric acid (HCl), and then sufficient water to carry the acid out of the trap of the thistle tube. *Do not apply any heat whatever. Do not collect any gas until the generator has been going for about two minutes, and do not attempt to light the gas as it issues from the generator.* Collect one or two cylinders of gas, adding more acid if necessary, always keeping the cylinders covered, mouth downward, because H is a light gas, and will readily escape if the cylinders are placed right side up.

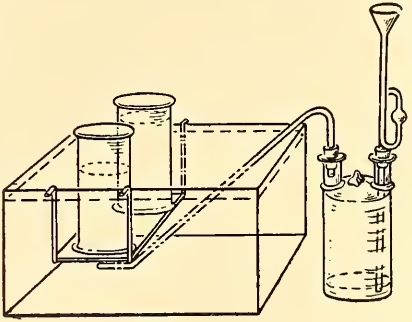


Fig. 17.—Apparatus for preparation of hydrogen.

When working with hydrogen in the laboratory, the student should always exercise care, because mixtures of hydrogen and oxygen are very explosive. Only a spark or a near-by flame is necessary to bring about an explosion.

Make the following test with hydrogen: Thrust a burning splinter into the mouth of the cylinder of hydrogen, as shown in Fig. 18.

Questions. (1) What is the color of H? (2) Odor? (3) Is it a light or heavy gas? (4) Does it support combustion? (5)

Is it combustible? (6) What is formed when H is burned? (7) How do you know that this product is formed? (8) From what compound was the H obtained? (9) What caused the H to be liberated from this compound? (10) Why are mixtures of H and O very explosive? (11) What other acids could be used in the preparation of H? (12) What other metals could be used in the preparation of H? (13) Give the equation for the reaction of the Zn and HCl. (14) What do these tests prove in regard to the character and properties of the element H?

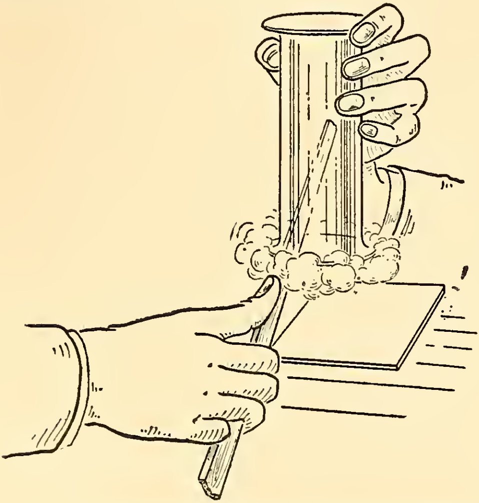


Fig. 18.—Thrusting burning splinter into hydrogen.

41. **Properties.**—Physically, hydrogen is characterized as a colorless, odorless, and tasteless gas. It is the lightest in weight of any of the elements, and for that reason is taken as the standard for the atomic weights. At a low temperature, and under pressure, hydrogen can

be liquefied; with greater difficulty, however, than any other element. Hydrogen is 14.43 times lighter than air. A liter of hydrogen, under standard conditions of temperature and pressure, weighs 0.08961 gram. Chemically, hydrogen is characterized as combustible, but not a supporter of combustion. It readily combines with many other elements, particularly oxygen, with which it forms water. When hydrogen and oxygen unite to form water, a reaction takes place which causes a contraction in volume. Two volumes of hydrogen and one volume of oxygen unite to produce two volumes of water-vapor or steam. When hydrogen and oxygen unite, there is always an explosion, due to contraction in volume. That water is produced when hydrogen is burned, can be demonstrated by placing a dry test-tube over a flame of hydrogen. The interior of the test-tube will become covered with moisture. Hydrogen does not unite with all elements as readily as does oxygen. When hydrogen is burned, the flame is nearly colorless because the combustion is complete, and there are in the flame no solid particles heated to incandescence. Hydrogen produces an exceedingly hot flame, and, when mixed

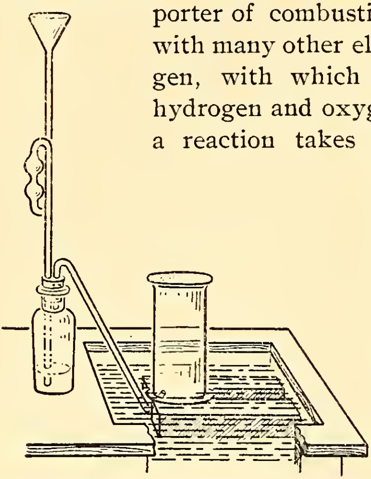


Fig. 19.—Preparation of hydrogen, using a wide-mouthed bottle and sink in place of a Woulff bottle and pneumatic trough.

with oxygen in the right proportion, as in the oxyhydrogen blowpipe, a high temperature is secured.

42. Importance.—Hydrogen is one of the essential elements for the formation of compounds present in plant and animal tissues, but because of its extreme lightness it never makes up a large portion by weight of a material. As a free element, it takes no part in life processes, but when combined with water, and in other forms, as in food materials where it is united with carbon and oxygen, it forms an essential part of compounds which are of much importance for animal and plant life.

Problem 1.—How many pounds of H will 100 pounds of Zn liberate when it is acted upon by H_2SO_4?

Problem 2.—How much $ZnCl_2$ is formed when 100 pounds of Zn are acted upon by HCl?

CHAPTER VI

Nitrogen

43. Occurrence.—Nitrogen occurs abundantly in a free state in the air, nearly four-fifths by weight being uncombined nitrogen. It also forms a part of some of the compounds which make up animal and plant tissues, where it is in chemical combination with carbon, hydrogen, and oxygen. Nitrogen is present also in the soil, forming a part of the decaying organic matter ; it is one of the elements of ammonia gas and ammonium compounds, and is present in combination with other elements, as in nitrates.

44. Preparation.—Nitrogen is usually prepared from air by removing the oxygen with which it forms a mechanical mixture. Since air is composed of both oxygen and nitrogen, if the oxygen in a given volume of air, as in a cylinder, is chemically united with phosphorus or carbon, forming soluble products, there is a residue of nitrogen left in the cylinder. Nitrogen produced in this way is not pure, but contains traces of other elements and compounds. For experimental purposes, it may, however, be considered as nitrogen. Nitrogen can also be produced from its compounds, as by the removal of the hydrogen from ammonia gas. The method of preparation in the laboratory is as follows :

Experiment 3.—Insert a long pin through the center of a large flat cork. Fasten a short piece of candle to the cork by means of the pin. Nearly fill the pneumatic trough with water. Light the candle and float it upon the surface of the water. Invert the large cylinder over the candle, having the mouth of the cylinder just below the surface of the water, as shown in Fig. 20. After the candle is extinguished, remove it by thrusting the hand through the water into the cylinder without admitting any

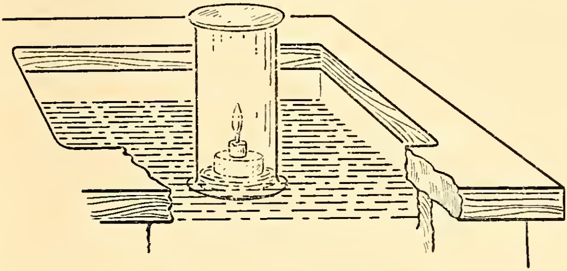


Fig. 20.—Preparation of nitrogen.

air. While still under water, cover the cylinder with a glass plate and remove from the trough. Then make the following tests :

(1) Insert a burning splinter into the cylinder of N. Observe the result. (2) Place a little sulfur in the deflagration spoon, ignite, and insert in the cylinder of N. Observe the result. (3) With a ruler, measure the height of the cylinder and the amount of water left in the cylinder.

Questions. (1) What is the color of N? (2) Odor? (3) Compared with air is it a heavy or light gas? (4) Is it combustible? (5) Does N support combustion? (6) Is N an active element? (7) What portion of the cylinder is filled with water in the preparation of N? (8) What portion of the cylinder is filled with N? (9) What portion of the cylinder did the O occupy? (10) What becomes of the products of the combustion of the candle? (11) What do these experiments prove in regard to the element N? (12) Complete the following table :

Name of element.	Symbol.	Combining wt.	Color.	Taste.	Odor.	Combustible.	Supporter of combustion.	Where found.
Oxygen								
Nitrogen								
Hydrogen								

When the candle is burned, the oxygen of the air in the cylinder unites with the carbon and hydrogen from the candle and forms carbon dioxid and water. The CO_2 is soluble in water, and the gas that is left is mainly nitrogen. The combination of the oxygen with the carbon causes a partial vacuum to form, and this results in the water rising in the cylinder. If great care is taken in performing the experiment, it will be found that the water will fill about one-fifth of the volume of the cylinder, occupying the space of the oxygen which has been combined with carbon. When all of the oxygen in the cylinder is combined with the carbon, the candle is extinguished because of lack of oxygen for combustion.

45. Properties of Nitrogen.—In general, the physical properties of nitrogen, except weight, are somewhat like those of hydrogen and oxygen, inasmuch as when pure, it is colorless, tasteless, and odorless. It is about 14 times as heavy as hydrogen, and only slightly soluble in water. At a low temperature and under pressure, it is liquefied, and at a still lower temperature and under higher pressure, it is solidified.

Chemically, nitrogen is unlike either hydrogen or oxygen. It is an inactive gas; it is neither combustible nor a supporter of combustion. When in the free state, it is one of the most inactive of all the elements, and will combine directly with only a few. When nitrogen enters into combination with other elements, particularly with carbon and hydrogen, forming the organic compounds, it has a tendency to make a weak link in the combination, and will readily split off and form simpler products. In the air, it serves the purpose of diluting the oxygen. No other element could perform this function as well as nitrogen. If the air were composed of pure oxygen, all combustion would be carried on in a rapid and wasteful way. Nitrogen is not a poisonous gas, but if an animal were compelled to breathe pure nitrogen, it would die because of the lack of oxygen. Some of the compounds of nitrogen decompose with violence, causing explosions. Nearly all of the explosives, as gunpowder, nitroglycerin, and guncotton, are compounds of nitrogen.

46. Importance.—The compounds of nitrogen take an important part in animal and plant life. In combination with carbon, hydrogen, and other elements, it forms the nitrogenous compounds present in plant and animal bodies. These compounds are called the organic nitrogenous compounds because they are capable of undergoing combustion, and produce volatile and gaseous products when burned.

In the study of the chemistry of foods, and of soils and fertilizers, the element nitrogen is given a prominent place. This is because it is one of the most expensive elements in commercial fertilizers, and foods which contain the nitrogenous compounds are the most expensive. Although nitrogen is found abundantly in the air, it is made use of as a plant food in an indirect way by only a limited number of plants. Nitrogen forms a large number of important compounds, as ammonia, nitrates, nitrites, amids, and the complex organic compounds, proteids. Some of these compounds will be studied more in detail in future chapters. To the agricultural student, nitrogen is one of the most important elements because of the rôle which it plays in plant and animal economy.

Problem 1.—Calculate the per cent. of N in $NaNO_3$.

Problem 2.—Calculate the per cent. of N in NH_3.

Problem 3.—Calculate the per cent. of N in $(NH_4)_2SO_4$.

CHAPTER VII

Carbon

47. Occurrence.—Carbon is found in the free state only in limited amounts, but is present in nature mainly in combination with other elements. With the mineral elements and oxygen, it forms carbonates, such as calcium carbonate or limestone. With hydrogen and oxygen, and a few other elements, it forms a large number of compounds of which plant and animal tissues are composed. All substances which char or blacken when burned contain this element in combination. Diamonds, coal, and graphite are forms of carbon in various degrees of purity. With oxygen, it is present in the air in small amounts as carbon dioxid. About half of the dry substance of wood and animal tissue is carbon. It occurs in nature in a great variety of forms.

48. Preparation.—In the form of charcoal, it can be prepared from wood, by the application of heat in the absence of air or oxygen, when a change known as destructive distillation takes place. The hydrogen, oxygen, and nitrogen are expelled, while the black mass of impure carbon and mineral matter is left. In the preparation of charcoal, the wood is piled and burned in suitable pits, which, after the combustion is well started, are covered with turf to protect the burning mass from the air. Charcoal can be produced on a small scale in the laboratory, in the following manner :

Experiment 4.—Place two or three small pieces of wood in a

Hessian crucible, and cover with sand. Heat the crucible until smoking ceases (see Fig. 21). Remove and examine the charcoal.

Questions. (1) What are the principal elements present in wood? (2) What becomes of these various elements when the material is heated? (3) Why was the sand used in this experiment? (4) What becomes of the ash or mineral matter in the process of charcoal-making? (5) What is charcoal, and of what element is it principally composed? (6) Does charcoal have a crystalline structure? (7) What would be the result if sand were not used in the experiment? (8) Give the equation for the combustion of carbon. (9) How can charcoal be made on a large scale?

Particles of carbon can also be obtained from a gas, candle, or lamp flame, by holding a piece of cold porcelain a little above the flame. Carbon, in the form of soot, is deposited in chimneys when fuel is burned with a poor draft. When combustion is complete, the carbon is oxidized, forming carbon dioxid. If a fire gives off a large amount of dense black smoke, the carbon is not completely oxidized, and consequently a loss of fuel value occurs.

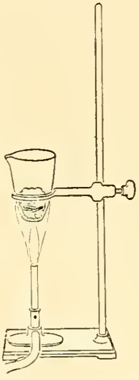


Fig. 21.—Preparation of charcoal.

49. Properties.—Carbon is found in three forms in nature: as diamond, graphite, and amorphous carbon. The diamond is a pure form of crystallized carbon. It is capable of being burned the same as any other form of the element, and produces carbon dioxid. Diamonds of small size can be produced artificially by the cooling of graphite from molten iron. Graphite is also a crystalline form of carbon, but the crystals are of different shape and color from diamonds. It is soft, and is used quite extensively as a lubricant. As it does not burn as readily as other forms of carbon, it is used frequently for making crucibles and for the linings of furnaces. It is a natural product and is also produced artificially by dissolving carbon in iron. There are a great many uncrystallized or amorphous forms of carbon, as lignite and soft coal, lampblack, and charcoal.

50. Coal.—All of the conditions under which coal has been produced are not known. It is supposed to be the result of the joint action of heat and pressure upon prehistoric forms of vegetation. Hard or anthracite coal is the purest form known, and yields the smallest amount of ash and unoxidized volatile products. Bituminous or soft coal is less pure as a larger amount of the carbon is present in chemical combination with the other elements, and when burned, the carbon is not as completely oxidized under ordinary conditions as is that of hard coal. Coal may contain a number of impurities, as sulfur and mineral matter. Cannel coal is a variety which contains a large amount of mineral oils.

Lignite is vegetable matter which has only partially undergone the coal-forming process. It is less pure than soft coal, and is supposed to be an intermediate stage in the formation. Peat is vegetable matter which has undergone chemical changes under water. It is less pure than lignite.

51. Allotropism.—An element which has the power to take on so many different physical forms as has carbon is called an allotropic element. Only a few elements have the properties of allotropism.

52. Carbon as a Reducing Agent.—Carbon is used extensively for the reduction of minerals. The action of carbon as a reducing agent may be observed from the following experiment:

Experiment 5.—Mix thoroughly 2 or 3 grams of copper oxid (CuO) and an equal bulk of charcoal (animal charcoal). Place the mixture in a small test-tube and apply heat. Observe the result.

Questions. (1) What is the bright red material produced in the test-tube? (2) What was the source of this material? (3) What caused the O to be separated from this compound? (4) What did it unite with? (5) What was formed as the product? (6) Write the reaction. (7) Why is carbon called a reducing agent? (8) What kind of an agent would CuO be called? (9) Why is carbon useful in separating minerals from their ores?

When carbon acts as a reducing agent, it unites with or abstracts the oxygen from the material reduced, forming CO_2. The process is called reduction because the oxygen is abstracted. When oxygen is added to a material, the process is just reversed, and is called oxidation. When reduction takes place, oxygen is abstracted from a material. When oxidation takes place, oxygen is added.

53. Combustion.—From the facts given in regard to oxygen and carbon, it is evident that combustion, in the ordinary sense, is simply the union of carbon with oxygen, and, as a result, light and heat are given off. If the process is a slow one, and heat without light is evolved, slow oxidation takes place. An example of slow oxidation is the rusting of metals. In slow oxidation, the total amount of heat evolved is the same as if the material underwent direct combustion. The regulation of drafts in stoves to influence the combustion of fuel so as to obtain the largest amount of heat, is based upon the simple laws of the combustion of carbon.

A candle or gas flame well illustrates the laws of combustion. The outer portion of the flame is a non-luminous envelope of gases undergoing perfect combustion; within this is a layer of gases undergoing partial combustion, and constituting the light-giving part of the flame; while in the center is a zone which is more perfectly cut off from the supply of air, and little or no combustion is taking place. The combustion of a gas or candle flame can be studied from the following experiment:

Experiment 6.—Structure of the flame. Unscrew the top of a Bunsen burner and make a drawing showing how the burner works, and the workings of the orifices at the bottom of the burner. Replace the parts of the burner, open the air-holes at the base, and light the gas. Hold a sheet of paper back of the flame and try to distinguish the three parts: (1) the outer non-luminous envelope of perfect combustion; (2) the inner luminous zone of partial combustion; (3) the central blue cone of unburned gas. Make a drawing of the flame. Press a piece of cardboard or paper down upon the flame for an instant and remove it before it takes fire. Observe the result. Hold a piece of wire close to the burner and observe that at first the wire does not become red at the center of the flame. Thrust the head of a match into the center of the flame for an instant and then remove it. If this is done quickly, the match can be removed before combustion takes place. Place a piece of wire gauze above the flame as shown in Fig. 23. Observe the result. Extinguish the gas. Hold the wire gauze

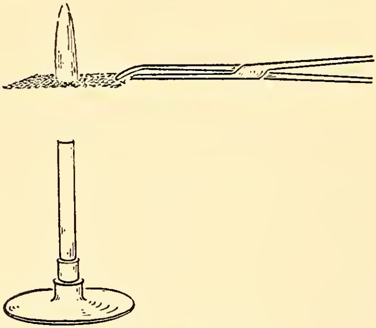


Fig. 22.—Combustion.

about an inch above the burner, then light the gas above the gauze (Fig. 22).

Questions. (1) Why was a charred circle formed when the piece of paper was pressed down upon the flame? (2) Why did the wire first redden near the outer portions of the flame and not at the center? (3) Why did the flame refuse to burn above the wire gauze, when the gauze was pressed down upon the flame? (4) When the gas was lighted above the gauze, why did it refuse to burn below? (5) What is kindling temperature? (6) What are the three conditions necessary for combustion? (7) What condition was lacking when the gauze was placed in the flame? (8) Why does a flame give light when the air is excluded from the burner, and give but little light when the air vent is open? (9) Does the amount of light which a flame produces indicate the amount of heat produced? Why? (10) What causes a flame to give light? (11) Why do some materials, when burned, produce more flame than others? (12) What is spontaneous combustion? (13) Explain how it is possible for clover or fodder to undergo spontaneous combustion in a barn. (14) What can be done to prevent spontaneous combustion? (15) Carbon, when burned, produces heat; limestone, $CaCO_3$, contains carbon; why is it not possible to use limestone for fuel?

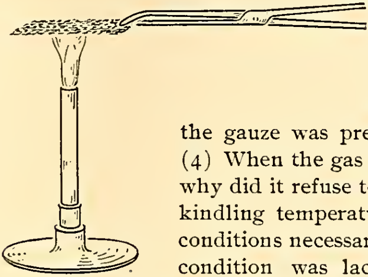


Fig. 23.—Combustion.

54. Spontaneous Combustion.—In order for a substance to undergo combustion, it is not necessary for a match or flame to be applied to the material. As soon as a substance is heated to its kindling temperature, that is, the temperature at which it unites with oxygen, if in the presence of air, combustion takes place, called spontaneous combustion. Clover, when stored in the mow in a damp condition, may undergo spontaneous combustion. The fermentation which takes place produces combustible gases which, at suitable temperature, ignite; the burning gases, in turn, ignite the carbon of the material. Substances containing a great deal of oil and materials of low kindling temperature, as carbon bisulfid, phosphorus and sulfur, under suitable conditions of temperature and air, readily undergo spontaneous combustion.

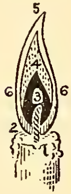


Fig. 24—Candle flame. 3. Non-luminous cone. 4. Luminous line. 5,6. Outer non-luminous envelope.

In case of fire, the laws governing combustion should be taken advantage of. If the fire is a small one, cut off the supply of air, and the fire is extinguished. This can be accomplished by the use of sand, wet blankets, or any material that will cut off the supply of air. In order for spontaneous combustion to take place, there must be (1) a combustible substance, which (2) is heated to a suitable temperature, and (3) in the presence of air.

55. Carbon a Decolorizer and Deodorizer.—Wood and animal charcoal have the power of absorbing gases and some coloring materials from solutions. In the manufacture of sugar, some of the impurities are removed by bone-black or animal charcoal filters, and in purifying water, charcoal filters are often used. The power of carbon to abstract gases and coloring-matter is largely a physical property. In the soil, the carbon compounds decay and produce humus, which has some of the physical properties of charcoal to absorb gases and soluble bodies.

Experiment 7.—Place in a cylinder two grams of animal charcoal, and about 1 cc. cochineal solution diluted with 10 cc. water. Cover the cylinder with a glass plate and shake; then pour the contents of the cylinder into a filter. If the first portion which filters, the filtrate, is not clear, pass it through the filter a second time.

Repeat the experiment, using 2 cc. potassium sulfid solution, 2 cc. hydrochloric acid, and 10 cc. water in place of the dilute cochineal solution.

Questions. (1) What effect did the animal charcoal have upon the color of the solution? (2) What property does this show animal charcoal to possess? (3) What was the result of filtering the potassium sulfid solution? (4) What property does this show animal charcoal to possess?

56. Products of Combustion.—The carbon dioxid gas given off from either a candle or a gas flame can be collected by arranging an apparatus like that shown in Fig. 25. A metal funnel is connected with a delivery tube which passes into a solution of lime water, $Ca(OH)_2$, in a test-tube. The carbon dioxid given off from the flame passes into the lime water and by forming calcium carbonate causes it to become cloudy. $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$. The carbon comes from the gas which undergoes combustion, and is combined with hydrogen as hydrocarbons. That a candle produces its own combustible gases can be proved by collecting some of the gas with a glass tube and rubber bulb as shown in Fig. 26. This gas can then be burned as indicated in Fig. 27. The

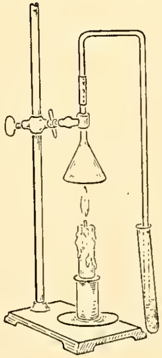


Fig. 25.—Collecting carbon dioxid from candle.

hydrogen of a gas or candle forms H_2O during combustion, and can be collected by passing the products of combustion through suitable absorbents. If a dry test-tube is held above the flame, a little moisture will collect on the sides of the test-tube.

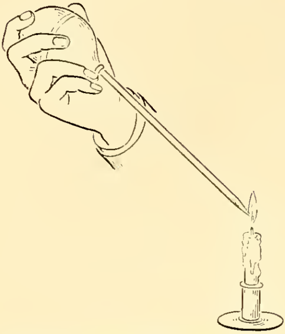


Fig. 26.—Obtaining unburned gas from candle.

57. Compounds of Carbon.—Chemically, carbon forms a very large number of compounds, more, in fact, than any other element. The carbon compounds present in plant and animal tissues are studied in a separate division of chemistry known as *organic chemistry*, while those compounds of carbon which are in combination with the mineral elements, as calcium, sodium, and potassium, are studied in *inorganic chemistry*. No well-defined boundary line, however, can be established between these two divisions of chemistry.

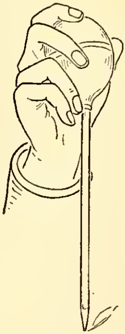


Fig. 27. — Combustion of gas from candle.

58. Importance of Carbon.—The compounds found in plant and animal bodies contain carbon in larger amounts than any other element; consequently the carbon compounds take a very important part in animal and plant growth.

Carbon is the element essential for the production of heat when fuels and foods are oxidized. Commercially, the compounds of carbon are of great importance as they are found in foods, fuels, and in all animal and plant products.

Carbon is found in the air in the form of carbon dioxid in sufficient amounts for the production of crops. It is also found in large amounts in human and animal foods; but because of its abundant presence, and its distribution in balanced form, it has not been considered to take such an important part economically in the production of plants as the element nitrogen. It is, however, equally important, although its natural distribution is such that it does not require as much effort, on the part of man, to obtain it as other forms of food materials. Nevertheless, the carbon compounds, particularly in food materials, should not be disregarded or considered of little or no importance because of their abundance. In the study of foods and the study of soils and fertilizers, some of the compounds of carbon are considered more in detail.

CHAPTER VIII

Water

59. Chemical Composition.—That water is composed of hydrogen and oxygen in approximately the proportion of 2 volumes of H to 1 of O can be demonstrated by passing a current of electricity through water and collecting the escaping gases. Oxygen will be liberated at the positive electrode, while hydrogen will be liberated at the negative electrode. That water is composed of 16 parts, by weight, of oxygen, to 2 parts, by weight, of hydrogen, can be demonstrated by passing hydrogen gas over copper oxid heated in a tube. The reaction which takes place is $CuO + 2H = H_2O + Cu$. If suitable provisions are made for weighing the oxid of copper used, and the water produced, it will be found that the weight of the water bears a definite relation to the oxid of copper reduced. For every loss of 16 grams of oxygen from the copper oxid, 18 grams of water are produced, showing that water is eight-ninths, by weight, oxygen.

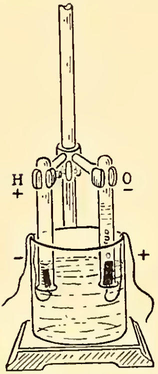


Fig. 28.—Electrolysis of water.

Experiment 8.—Distillation of water. Connect flask A (Fig. 29) with the bent tube B to the condensing apparatus issued for this experiment. Place the distilling flask upon the sand-bath and in position as shown in Fig. 29. Fill the tank of the distilling apparatus, and half fill the flask, with water. Apply heat to the flask, and reject the first portion of water that is distilled. Distil about 25 or 30 cc. of water.

Tests. (1) Thoroughly clean out your porcelain evaporating dish, if necessary using a little white sand for scouring, rinse with distilled water, and then by placing the evaporator upon a sand-bath, evaporate some of the distilled water to dryness. Carefully regulate the heat so that as the water evaporates there will be less and less heat. This is to prevent the breaking of the evaporating dish by too much heat at the close. Examine the evaporating dish. See if there is any residue. (2) Evaporate to dryness a similar amount of ordinary water, and observe the residue.

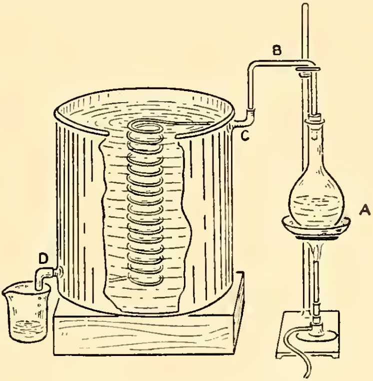


Fig. 29.—Distillation of water.

Questions. (1) Why do the contents of flask A become cloudy after boiling and cooling? (2) Why was the residue obtained by one test and not by the other? (3) What became of the residue when the water was distilled? (4) How could you distil water on a larger scale for drinking purposes, if necessary to do so?

60. Physical Properties.—When water cools, it reaches its maximum density at 4° C; below this point, it expands, and hence ice has a lower specific gravity than water. All natural waters contain more or less impurities in the form of mineral and vegetable matter and gases. Pure water can be prepared only by distillation. When a substance, as salt, is dissolved in water, a solution is obtained. The particles of the material are separated in the process of solution, and every part of the solution, even though dilute, contains some of the dissolved substance. When a substance is dissolved, *ions* are produced. They are small masses of the material that have undergone changes due to the action of the solvent. The ions possess definite electrical properties. When a substance goes into solution, the process is both physical and chemical. In some cases a change of temperature occurs, as when ammonium nitrate solution is made.

16. Water of Crystallization.—Many substances contain, in chemical combination, water necessary for the formation of crystals. This is what is meant by water of crystallization. Without this water, crystals could not be formed. The amount of water required bears a definite relation to the composition of the crystals. When copper sulfate crystallizes, 7 molecules of water of crystallization are added to the substance. In purchasing some substances, as sulfate of soda, a large amount of water is obtained, as this compound contains 10 molecules of water of crystallization. When the substance is heated in an oven, to a sufficiently high temperature, usually above 100° C., the water of crystallization is expelled and the anhydrous substance is obtained. Water of crystallization is entirely different from hydroscopic moisture or moisture which is absorbed from the air. Some chemical compounds, when exposed to the air, give up their water of crystallization. Such substances are called efflorescent. Other compounds, as KOH and $CaCl_2$, absorb moisture from the air. Such substances are called deliquescent. Water takes an important part in chemical reactions ; in fact, many of the reactions expressed in the form of equations could not take place without the presence of water.

62. Natural Waters.—Rain, spring, lake, river, and sea waters are some of the principal forms in which water is found in nature. Some waters contain a sufficient amount of dissolved salts to give them definite characteristics. Such are known as mineral waters. The most common impurities in water are lime, magnesia, potash, soda, and iron compounds. These substances give properties to the water which cause them to be characterized as hard or soft, according to the nature and amount of minerals dissolved. All natural waters are liable to contamination, and the organic impurities of water serve as food for disease-producing organisms. The sanitary condition of the water supply has an important bearing upon health. Typhoid fever, cholera, and other bacterial diseases are frequently caused by poor drinking water. The spores of the organisms present in the water are taken into the body where they rapidly multiply. Surface wells, particularly when near barns and dwellings, and in thickly settled regions, are frequently in an unsanitary condition.

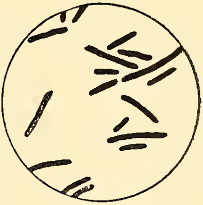


Fig. 30.
Typhoid bacillus.

63. Impurities in Water.—The nature of the impurities in the soil through which water flows determines the kinds of impurities in the water. If a soil is polluted with decaying animal and vegetable refuse matters, the soluble parts of these materials along with the countless organisms which they contain, become a part of the drinking water. The impurities in well waters are (1) organic matter, and (2) mineral salts. When waters are charged with excessive amounts of organic matter, the solids obtained by evaporating the water to dryness blacken when ignited. The carbon compounds in a liter of some water will require 20 mgs. or more of oxygen for oxidation. The organic matter may decompose and become harmless, but it is liable, in times of epidemics, to furnish food for disease germs.

A water that is comparatively free from organic matter is not nearly so apt to be a source of trouble by conveying disease germs as one that contains a large amount of organic refuse, as this is the best kind of food for the development of germs which cause many of the most fatal diseases. Vegetable matter, as a rule, is not as harmful in a water as is animal matter. The organic matter that is dissolved in waters is constantly decaying ; this decomposition is the result of the workings of minute organisms known as bacteria, and the disease-producing bacteria may be present as well as the harmless kinds. The history of the water supply of large cities has shown that a water which is comparatively free from organic matter is the best for household purposes. The reasons are obvious. Excessive amounts of nitrogenous organic matter in drinking waters are particularly objectionable, as the source of this material is often sewage or surface drainage, as from a swamp.

Deep well waters are less liable to be contaminated with organic impurities than surface wells, but a deep well is not above suspicion because the layers of soil are subject to changes in slope, and the water from a deep well may receive surface drainage from some distant place, as indicated in the illustration (Fig. 31). Although the soil would remove a portion of the impurities and the organic matter would be partially oxidized, the water would not be entirely free from contamination.

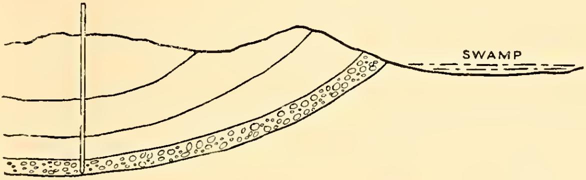


Fig. 31—Well contaminated with drainage from swamp.

64. Location of Wells.—The well should be remote from barns and cesspools. Large trees about wells are objectionable because the water is fouled by waste matter thrown off by the roots. The top of the well for 6 or 8 feet should be laid with cement. The well platform should be tight so that small animals are kept out. Drain water from the spout should be carried away from the well platform and the watering trough should not be directly over the well. The land should slope away from the well and the surfacing should be of clay. The well should have ventilation, and should occasionally receive a cleaning.

65. Mineral Impurities.—Calcium carbonate, calcium sulfate, sodium chlorid, and sodium sulfate are the most common minerals present in water. In alkali waters the mineral impurities consist of large amounts of sodium or potassium compounds, and there is no way of improving

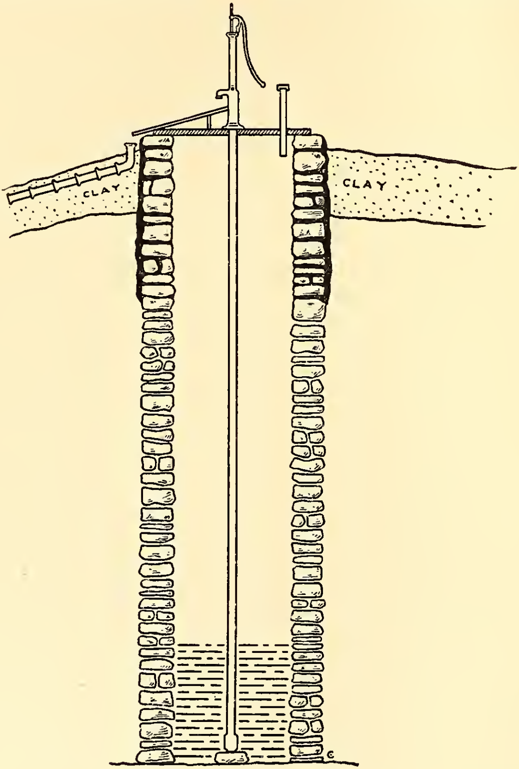


Fig. 32.—Construction of well.

such waters except by distillation. Different kinds of mineral matter, if present in excessive amounts, may impart medicinal properties; magnesium sulfate (Epsom salts) acts as a purgative, while calcium sulfate causes costiveness. Strong alkaline waters can generally be detected by their salty taste.

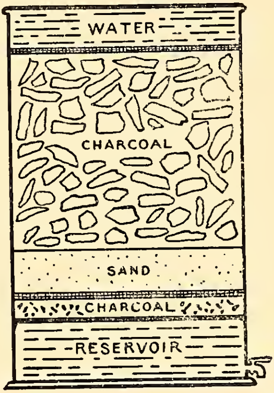


Fig. 33.—Charcoal water filter.

The presence of a large amount of limestone in waters is not so serious as the presence of other minerals. Waters sometimes contain limestone to such an extent that when boiled they become cloudy, which is because of the removal of the carbonic acid gas; this caused the limestone to remain in solution. Waters that contain limestone are not generally considered injurious to health although they are not so satisfactory for cleaning purposes on account of the lime acting upon the soap and forming a scum of insoluble lime soap. A large amount of limestone, gypsum, etc., is what causes waters to be hard. Some waters contain iron compounds, as carbonate of iron which, upon contact with the air, forms hydrate of iron, and is deposited as a brownish red sediment. Some waters contain so much mineral matter that when

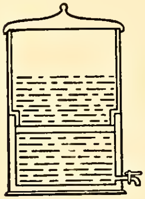


Fig. 34.—Unglazed porcelain filter.

used for generating steam they produce a large amount of boiler scale. This can be partially prevented by the use of materials containing tannic acid.

66. Methods of Improving Drinking Waters.—(1) By boiling, which destroys disease-producing organisms. Boiled or sterilized water, however, is not free from the poisonous compounds which many organisms produce. In cases of pestilential diseases, water should always be boiled.

(2) By filtering through charcoal or through disks of unglazed porcelain-like material, which results in removing a large part of the organic matter. Special care, however, should be taken to keep the filter clean, otherwise it will be a source of contamination. Boiling the water before filtering also improves its sanitary condition. One of the most effectual forms of water filters is the Pasteur filter, in which the water passes through a series of tubes which present a large surface area for filtering.

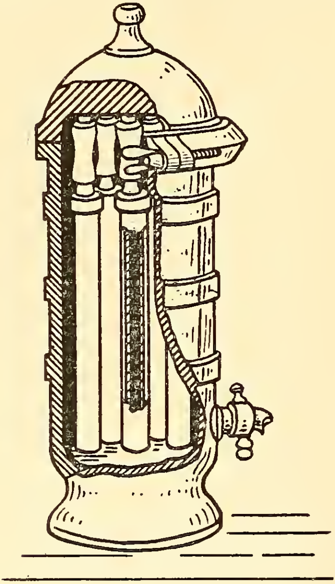


Fig. 35.—Pasteur water filter.

(3) By distilling, which removes all mineral impurities, and the water is also purified from organic matter. It is the most effectual way of removing all kinds of impurities and rendering the water free from organisms, and safe for use.

CHAPTER IX

Air

67. Air a Mechanical Mixture.—Air is a mechanical mixture composed of a number of gases and compounds in about the following proportions: (1) nitrogen, 79 per cent.; (2) oxygen, 20 per cent.; (3) carbon dioxid, 0.04 per cent.; (4) ammonium compounds in small amounts; (5) moisture; (6) ozone; (7) hydrogen peroxid; (8) argon; (9) dust: organic matter, and micro-organisms. That air is a mechanical mixture is shown by its not having a constant chemical composition, which is necessary for all compounds, and when nitrogen and oxygen are mixed, in the same proportion as in air, there is no evidence of a chemical reaction, as change of volume or temperature. The air that is dissolved in water is of different composition from atmospheric air, due to the fact that oxygen is more soluble in water than is nitrogen. The occurrence of nitrogen and oxygen in the air, and the chemical and physical properties of these gases have been discussed in Chapters IV and V.

68. Carbon Dioxid.—The amount of carbon dioxid in the air is small, about 0.04 per cent., and it is supposed to remain fairly constant in amount. It is produced from: (1) combustion of carbon-containing materials, as fuels; (2) decaying of organic matter; and (3) respiration of animals. The carbon dioxid of the air serves as food for plants and is used for the construction of plant tissue. The amount produced and that used by vegetation nearly balance each other, so that the carbon dioxid in the air remains fairly constant. While the percentage amount in the air is small, the total amount is quite large; it is estimated that over each acre of the earth's surface, there are about 30 tons of carbon dioxid at the disposal of plant bodies. Carbon dioxid itself is not such a poisonous gas, but it is usually associated in respired air with noxious and poisonous products thrown off by the lungs. Hence the amount in a room is taken as the index of the completeness of ventilation. Whenever the carbon dioxid in a room exceeds 0.1 per cent., the poisonous products associated with it are

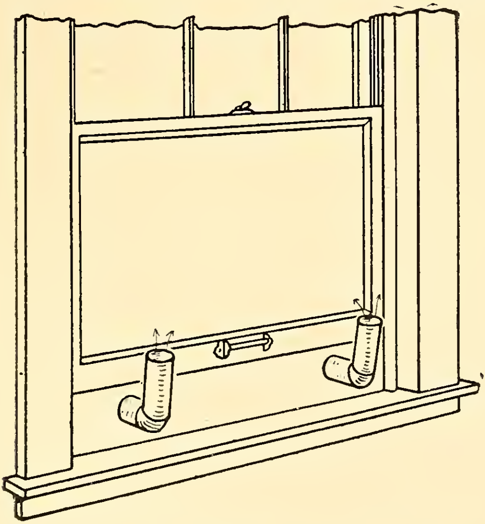


Fig. 36.—Ventilating board in window for obtaining fresh air.

considered to be too large in amount for perfect sanitary conditions. While carbon dioxid is a product of respiration, and is of no direct economic importance to animals, it is indirectly of great importance because of its serving as food for plant bodies. It is a heavy gas, but in a room it diffuses and is quite evenly distributed. Its presence in pure and in respired air can be shown by the following experiment:

Experiment 9.—Pour 10 cc. of lime water (calcium hydrate) into a test-tube, and blow through it, using for the purpose a clean glass tube. Observe the precipitate of calcium carbonate. Expose about 10 cc. of lime water in a beaker for twenty-four hours, and observe the result. The reaction which takes place between the lime water and the carbon dioxid of the air is as follows:

$$Ca(OH)_2 + CO_2 = CaCO_3 + H_2O.$$

Questions. (1) What caused the precipitate to form? (2) What was produced? (3) Is $CaCO_3$ soluble in water? (4) How do you determine whether or not a gas is CO_2? (5) How does the product from this experiment compare with that from the burning candle?

In the ventilation of dwellings, barns and stables, it is necessary that the products of respiration be removed as completely as possible and not allowed to accumulate and endanger health. Pure air is as important as pure food or water. Impure air is frequently the cause of disease and indirectly it may, by lowering the vitality of the individual, prepare the way for disease. When gasoline or kerosene is used as fuel, more thorough ventilation is necessary than when wood or coal is used, because the products of combustion from the gasoline and kerosene are given off into the room instead of being carried out through the chimney. The subject of ventilation, which forms a part of sanitary chemistry, is, as a rule, given too little attention.

69. Ammonium Compounds.—When nitrogenous organic compounds decay, ammonia gas, NH_3, is given off.

Since nitrogenous animal and vegetable matters are constantly undergoing decay, some ammonia is always present in the air. The ammonia gas unites with the carbon dioxid and forms ammonium carbonate. In barns and stables, where the ventilation is poor, abnormal amounts of carbon dioxid and ammonia are formed from the respiration and waste products of animals. When carbon dioxid forms to such an extent that it produces a white coating upon stones and boards, it shows enough ammonium carbonate to be injurious to animals. Nitrogen, in traces, in the form of ammonium nitrate and nitrite, is also present in the air. The amount of combined nitrogenous compounds in the air is small and is not sufficient to furnish food for plants.

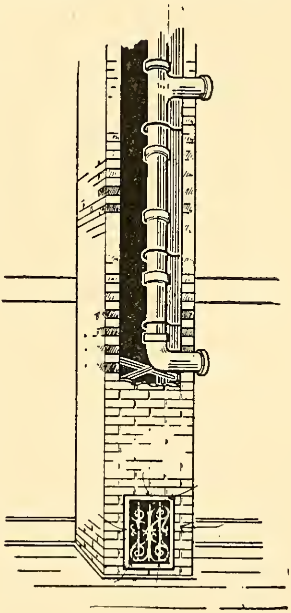


Fig. 37.—Ventilating flue in chimney for removing foul air.

70. Moisture.—The amount of moisture in the air ranges between wide limits, from complete saturation to desert conditions. When the air contains all the moisture it can hold, it is said to be saturated. Under ordinary conditions, the humidity, or per cent. of saturation ranges between 60 and 85. The amount of moisture in the air has an influence upon plant growth, rather because it modifies the conditions of the atmosphere than because it furnishes moisture directly for plant growth. The humidity of the air also influences many farm operations, as the curing of cheese, which is best effected in an atmosphere containing about 85 per cent. of moisture.

71. Ozone and Hydrogen Peroxid.—These are oxidizing agents, present in the air only in traces. Ozone is a modified or allotropic form of oxygen. It is more active than ordinary oxygen. Hydrogen peroxid (H_2O_2) readily gives up one of its atoms of oxygen for oxidation purposes. $H_2O_2 = H_2O + O$.

72. Argon and Helium are elements which are present in the air in small amounts. Argon makes up about 1 per cent. of the volume of the air, and is like nitrogen in many of its chemical characteristics, but is even more inactive and inert than nitrogen; it is the most inactive element known. Argon is not supposed to take any direct part in animal or plant life.

73. Organic Impurities.—The amount of dust, dirt, and impurities in the air varies with the conditions, as rainfall, local influences, and sources of contamination. Fine particles of dust, containing decaying vegetable matter, are carried long distances by the wind. This decaying vegetable matter often contains spores of disease germs. The dust and impurities in the air can be observed when a beam of sunlight finds its way into a room; then the particles of dust will be seen floating in the air. When the air in a room is not in motion, the dust particles separate and settle very much as fine clay separates from water which is not disturbed. There are many different kinds of organic impurities present in the air. The most objectionable of these are decayed refuse matters, particularly of animal origin. The air which passes over swampy, undrained land, is contaminated with impurities.

74. **Air as a Source of Food.**—In both animal and plant life, air plays an important rôle. It contains oxygen necessary for the existence of animals and carbon dioxid essential as food for plants. Over 90 per cent. of the total food of our agricultural and useful plants is obtained from the air as carbon dioxid, or from rain which finds its way into the soil. Food which is oxidized in the body requires oxygen for combustion. Hence it will be seen that the air is the source of the larger portion of the total food of both plants and animals.

CHAPTER X

Acids, Bases, Salts, and Neutralization

75. Classification of Elements.—Elements are divided into two classes: (1) Acid-forming elements and (2) base-forming elements. This division is made according to the properties of the elements.

The basic elements are commonly called metals: iron, copper, silver, and lead are examples. The basic elements form, with H and O, bases or hydroxids, as KOH and NaOH. A base is a compound composed of a metal in combination with OH, the hydroxyl radical. This radical can be replaced by an acid-forming element.

An acid is a compound containing hydrogen which can be replaced by a metal. In the preparation of hydrogen, the H of HCl was replaced with zinc. The acid-forming elements, with hydrogen, and with H and O, form acids.

Bases and acids are opposite in character and properties. Acids color blue litmus red, bases color red litmus blue. For purposes of study, the different acid- and base-forming elements are subdivided into families and groups which have definite relationships and common characteristics.

76. Salts.—When an acid and a base are brought together, a chemical reaction takes place known as neutralization. The product formed by the reaction is a salt. A salt is a compound formed by the union of acid-

and base-forming elements. Salts are neutral compounds. In the study of acids, bases, and salts, the character of the compound can always be determined from the formula as $Ca(OH)_2$. Calcium hydrate is a base because it contains the hydroxyl radical OH. $CaCl_2$ is a salt because it is composed of the acid-forming element Cl and the base-forming element Ca. HCl is an acid because it is composed of hydrogen and the acid-forming element Cl and the H can be replaced by a metal. Acids and bases do not exist as such to any appreciable extent in nature. Salts are neutral compounds and the materials most extensively found. In the table, Section 15, the characteristic properties of some of the elements as acid- or base-forming, are given. A few elements, as will be discussed later, have both acid and basic characteristics.

77. **Radicals.**—A radical is a group of elements which enters into chemical combination like a single element. When three elements combine to form a compound the combination is made in the following way: Two of the elements first form a radical, and then this radical combines with the third element. Every radical has its own valence which is independent of that of its separate atoms. A radical can exist only in chemical combination; it cannot be separated. Its individuality as a radical exists only when in combination. The elements which unite to form a radical do not do so according to the law of valence. There are only a few of the more common radicals which require special study at this stage of the work. Example: When H, S, and O combine, the S and O first form a radical, SO_2, which has a valence of 2. Two

atoms of H combine with one SO_4 radical and form H_2SO_4. Some of the more common radicals are:

Radical.	Valence.	Compounds formed with H.	Compounds formed with metals.
CO_3	2	Carbonic acid	Carbonates
ClO_3	1	Chloric acid	Chlorates
NO_3	1	Nitric acid	Nitrates
PO_4	3	Phosphoric acid	Phosphates
NH_4	1	....	Ammonium compounds
OH	1	Water	Hydroxids
SiO_3	2	Silicic acid	Silicates
NO_2	1	Nitrous acid	Nitrites
SO_3	2	Sulfurous acid	Sulfites
SO_4	2	Sulfuric acid	Sulfates

78. Naming of Acids.—Acids are named according to the characteristic acid element or radical present, as sulfuric acid, H_2SO_4, in which S is the characteristic acid element. The most common acids have the ending *ic*. Some acids have an *ous* ending, as H_2SO_3, sulfurous acid. The acid which has the smaller amount of oxygen has the ending *ous*, while the acid which has the larger amount of oxygen has the ending *ic*.

Name the following acids: HNO_3, HNO_2, H_2SO_4, H_2SO_3, H_3PO_4, H_3PO_3, H_3AsO_4, H_3AsO_3.

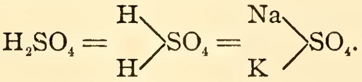
79. Naming of Bases.—Bases are named according to the characteristic base element which they contain. All bases are called hydroxids, as calcium hydroxid, $Ca(OH)_2$, and potassium hydroxid, KOH.

The rule in regard to the endings *ic* and *ous* applies in the case of bases as well as in that of acids; that is, when an element forms two hydroxids, the ending *ic* is applied to the one with the larger amount of hydroxyl, and the ending *ous* to the one with the smaller amount.

Name the following bases: $Mg(OH)_2$, NH_4OH, $NaOH$, $Fe(OH)_2$, $Fe(OH)_3$, $Al(OH)_3$, $CuOH$, $Cu(OH)_2$.

80. Naming of Salts.—Salts are named according to the acid and base elements which they contain, as K_2SO_4, potassium sulfate, composed of potassium, K, and the sulfate radical, SO_4. Most salts have an ending *ate*. A few have an ending *ite*. The salts derived from the acids with the *ic* ending always have the *ate* ending, as sulfuric acid, which always produces sulfates, phosphoric acid, phosphates, and nitric acid, nitrates. The acids ending with *ous* produce salts which end in *ite*, as nitrous acid always produces nitrites, and sulfurous acid, sulfites. Salts that are composed of only two elements always have an ending of *id*, as sodium chlorid, NaCl, and sodium sulfid, Na_2S.

81. Double Salts.—A double salt is one that is composed of two base elements in combination with one acid radical, as $NaKSO_4$, sodium potassium sulfate. Double salts are formed from acids which contain two replaceable hydrogen atoms, as H_2SO_4, by replacing one of the H atoms with one base element and the remaining H atom with another base element. This is represented graphically as follows :



$$H_2SO_4 = \begin{matrix} H \\ H \end{matrix}\!\!>\!SO_4 = \begin{matrix} Na \\ K \end{matrix}\!\!>\!SO_4.$$

82. Acid Salts.—An acid salt is one in which only a part of the H of the acid has been replaced. An acid salt always contains H, a metal, and a radical. $HNaSO_4$ is acid sodium sulfate, as only one H atom has been replaced with Na. A normal salt contains no replaceable H.

83. Basicity of Acids.—Acids with one replaceable H atom are called monobasic acids, as HCl and HNO_3. Acids with two H atoms are dibasic, as H_2SO_4, H_2SiO_3, and H_2CO_3. When an acid contains three replaceable H atoms, it is tribasic, as H_3PO_4.

84. Two Series of Salts.—When a base element has more than one valence, it forms two series of salts. For example, Fe has a valence of 2 and 3. The first series of salts is known by the ending *ous*. The second series has an *ic* ending. The one ending means that the compound is formed from the lower valence of the element, as $FeCl_2$, ferrous chlorid, while $FeCl_3$ is called ferric chlorid. There are two series of copper salts; CuCl is called cuprous chlorid, and $CuCl_2$, cupric chlorid.

Name the following salts: $FeCl_2$, $FeCl_3$, $FeSO_4$, $Fe_2(SO_4)_3$, $Fe(NO_3)_2$, $Fe(NO_3)_3$, $Fe(OH)_2$, $Fe(OH)_3$, HgCl, $HgCl_2$, $SnCl_2$, $SnCl_4$, $MnCl_4$, $MnCl_2$.

Experiment 10.—Neutralization and preparation of salts. Obtain two burettes from the instructor for these experiments. Measure out 5 cc. of concentrated HCl and 95 cc. of water; after mixing, fill one of the burettes with this diluted HCl (Fig. 38). Use your funnel for filling the burette, and then carefully wash the funnel. Prepare a dilute solution of NH_4OH, using 90 cc. of water and 10 cc. of the shelf NH_4OH. After mixing, fill the second burette with this preparation of diluted NH_4OH. Before using the solution in the burette, it should be lowered to the zero-point by carefully opening the pinch-cock. Always allow the tip of the burette to be filled with the solution before beginning the experiment.

Into a small beaker, measure from the burette exactly 20 cc. NH_4OH, with 10 or 12 drops of cochineal solution, which is changed to a deep purplish color by the alkali; then slowly add HCl from the other burette, constantly stirring the solution in the beaker until a decided change in color is observed. When all of the NH_4OH has been neutralized, the solution has a yellowish red color. Note the number of cubic centimeters of HCl used for neutralizing the 20 cc. of NH_4OH solution. Add a drop or two from the NH_4OH burette and note if there is a change of color. When the solution is neutralized, one or two drops of HCl or NH_4OH should give a decided change of color. If too much acid has been used, add a measured amount from the NH_4OH burette until the solution is neutralized. Finally note the total quantity of HCl and NH_4OH used. Repeat this experiment, using 20 cc. of the HCl solution.

Questions. (1) What was formed when the HCl neutralized the NH_4OH solution? (2) Write the reaction. (3) What would be the result if the neutralized solutions were evaporated to dryness? (4) Calculate the amount of HCl required to neutralize 1 cc. of NH_4OH.

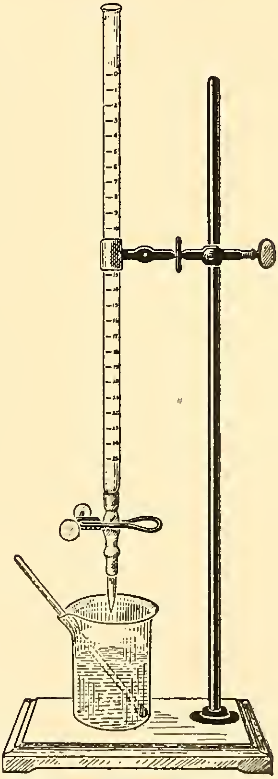


Fig. 38.—Burette.

Experiment 11.—Neutralization. Repeat Experiment 10, using dilute H_2SO_4 and NaOH solutions that have been prepared for this experiment. After completing the experiment, *clean the burettes thoroughly and return them to the instructor.*

Questions. (1) What was formed when H_2SO_4 neutralized NaOH? (2) Write the chemical reaction. (3) What was formed as the products of this reaction? (4) How can the salt product be obtained? (5) In writing the reaction, why do we use 2NaOH instead of NaOH? (6) How does the product of Experiment 10 differ from the product of Experiment 11? (7) What other acids could be used for neutralizing NaOH and NH_4OH? (8) What other bases could be used for neutralizing HCl and H_2SO_4? (9) What is an acid? (10) What is a base? (11) What is a salt? (12) Which do we find most abundantly in nature, acids, bases, or salts? Why?

Experiment 12.—Preparation of a salt. Put 10 cc. dilute HCl and 10 cc. water into the evaporator. Measure out 10 cc. of NaOH into a beaker and add 50 cc. water. Add this diluted NaOH to the evaporator a little at a time until the solution is neutral to litmus paper. Do not dip the paper into the solution, but transfer a drop by means of a glass rod from the evaporator to the paper. In case too much NaOH has been used, add a drop or two of the acid. Bases or alkalies turn red litmus paper blue, while acids turn blue litmus paper red. When the solution is neutral, it has no perceptible action upon litmus paper. Place the evaporating dish upon the sand-bath, and apply heat until the solution is evaporated to dryness. Carefully regulate the flame so as to avoid excessive heating. This will prevent spattering when the solution becomes concentrated.

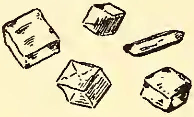


Fig. 39.—Sodium chlorid crystals (common salt).

Questions. (1) What is left in the evaporator? (2) From what was it produced? (3) Write the chemical reaction. (4) Taste some of the material in the evaporating dish. How is it possible for this material to be formed from two such unlike compounds as HCl and NaOH? (5) What is neutralization? (6) Are definite amounts by weight of HCl and NaOH required for neutralization? (7) How many molecules of HCl are required to neutralize one of NaOH? (8) How much does a molecule of HCl weigh? (9) Of NaOH? (10) How many parts by weight of each must be taken for neutralization? (11) How does this illustrate the law of definite proportion?

CHAPTER XI

Hydrochloric Acid, Chlorin, and Chlorids

85. Occurrence.—The element chlorin is never found in a free state in nature, but is always in combination with other elements, as with sodium, forming sodium chlorid. With hydrogen, chlorin forms hydrochloric acid.

86. Preparation.—Hydrochloric acid is produced by the action of H_2SO_4 on NaCl, the reaction being $2 NaCl + H_2SO_4 = Na_2SO_4 + 2HCl$. Heat is applied and the hydrochloric acid gas is expelled and collected in water. In the preparation of hydrochloric acid, the Cl part of the compound is supplied by the NaCl, while the sulfuric acid furnishes the hydrogen. Hydrochloric acid can also be made by direct union of the elements hydrogen and chlorin. It is prepared in the laboratory in the following way:

Experiment 13.—Preparation of hydrochloric acid. Arrange the apparatus as shown in Fig. 40. A sand-bath, containing sand, is placed upon either the tripod or the large ring of the iron ring-stand. Tube B connects flask A with Woulff bottle C, which contains 100 cc. of water. The tube is made from a piece of glass tubing 22 to 24 inches long, with one right-angled bend about 3 inches from the end, and another, parallel and about 6 inches from the first bend. This tube is connected with both flask A and the Woulff bottle by means of tight-fitting corks. Tube B passes into the bottle but *not* below the surface of the liquid. Through a tight-fitting cork in the middle neck of Woulff bottle C passes a safety tube so adjusted that it dips just below the surface of the water in C. This safety-tube is a straight piece of glass tubing, 9 or 10 inches long. Woulff bottle C is connected with a second Woulff bottle by means of a bent tube which passes below the water in the second bottle but is above the water in the first bottle. The apparatus, as constructed, allows the gas which is generated in flask A to pass through into C and saturate the water. Some of the acid passes over into the second Woulff bottle. Since the delivery tubes in C do not pass below the surface of the liquid, and the pressure is equalized, no liquid can be drawn back into flask A.

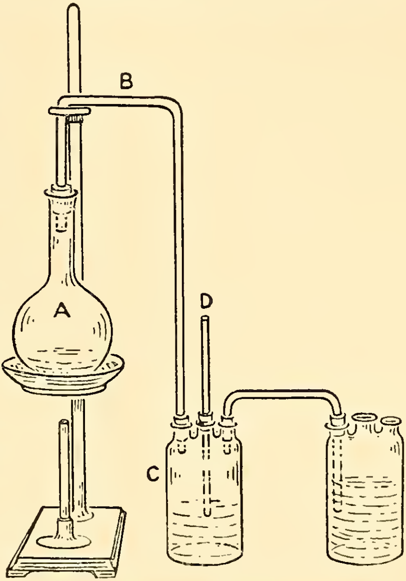


Fig. 40.—Preparation of hydrochloric acid.

Place 15 grams sodium chlorid (NaCl, common salt) and 30 cc. of concentrated H_2SO_4 in flask A. Apply heat to the flask, and after ten minutes remove the burner and test the liquid in both Woulff bottles with litmus paper. Then make the following tests:

(1) Disconnect the delivery tube and test the escaping gas with wet litmus paper. (2) Collect a little of the gas in a test-tube, and test it with a burning splinter. (3) Put 2 or 3 cc. of silver nitrate ($AgNO_3$) into a test-tube and then a like amount of HCl from the first Woulff bottle. Observe the result. (4) Leave the test-tube and contents exposed to strong sunlight for a few minutes. (5) Put a small piece of zinc into a test-tube and cover it with some of the acid from the first Woulff bottle. Observe the result.

Questions. (1) What chemical reaction took place when H_2SO_4

and NaCl were brought together? (2) Is HCl a solid, liquid, or gas? Why? (3) Color? (4) Is it soluble in water? Why? (5) What was formed when the HCl was added to the test-tube containing $AgNO_3$? Give the reaction. (6) Is HCl combustible or a supporter of combustion? (7) What is a chlorid? (8) What effect would HCl gas have upon plants?

87. Properties.—Hydrochloric acid is a colorless gas, soluble in water. When exposed to the air, it combines with the moisture of the air. The concentrated acid used in the laboratory is a solution of about 40 per cent. HCl. Chemically, HCl is an active acid, and is neither combustible nor a supporter of combustion. When it neutralizes bases, chlorids are always formed. Hydrochloric acid is distinguished from other acids by its reaction with silver nitrate, a white precipitate of silver chlorid being produced which is soluble in ammonia and is blackened in sunlight. Hydrochloric acid is used extensively in the laboratory in the preparation of various compounds, and for the production of chlorin.

88. Preparation of Chlorin.—Chlorin is prepared by the action of an oxidizing agent, as manganese dioxid, upon hydrochloric acid, manganese chlorid, water, and chlorin gas being formed as products. The reaction is $MnO_2 + 4HCl = MnCl_2 + 2H_2O + 2Cl$. In this reaction the valence of manganese is changed from 4 to 2, and as a result free chlorin gas is liberated. The method of preparation in the laboratory is as follows:

Experiment 14.—Preparation of chlorin. It is preferable to set up the apparatus for generating chlorin under one of the hoods. Arrange the apparatus as shown in Fig. 41. Place 10 grams of MnO_2 and 15 or 20 cc. of HCl in flask A. By means of the delivery tube B, and a tight-fitting cork, the Cl gas, when generated, passes into the large cylinder, in which has been placed a green leaf, a piece of colored cloth, and paper upon which is some writing. The delivery tube passes through the hole in the ground-glass plate, without any cork. To generate the chlorin, apply gentle heat to the flask, and as soon as the cylinder is nearly filled with the Cl gas, which can be observed by its color, remove the flame so as to prevent any of the gas from escaping into the room. Do not inhale any of the fumes, as they are irritating to the throat and lungs. Make the following tests:

(1) Observe the effect which the chlorin gas has upon the cloth, paper, and leaf. (2) To the cylinder, add 5 cc. water containing two or three drops of indigo solution. Observe the result.

Questions. (1) Give the physical properties of Cl gas, odor, weight, and color. (2) What caused the liberation of the Cl gas from the HCl? (3) Write the reaction. (4) What are some of the chemical properties of chlorin as observed from the changes which have taken place in the materials in the cylinder? (5) What is a chlorid? (6) Name five compounds containing chlorin. (7) Why is Cl gas employed as a disinfectant? Explain its action as a disinfectant. (8) What is bleaching-powder, and how is it used as a disinfectant? (9) NaCl is necessary for animal life; Cl is one of the elements of the compound; Cl is destructive to animal life; why can you not conclude that NaCl containing Cl is destructive to animal life?

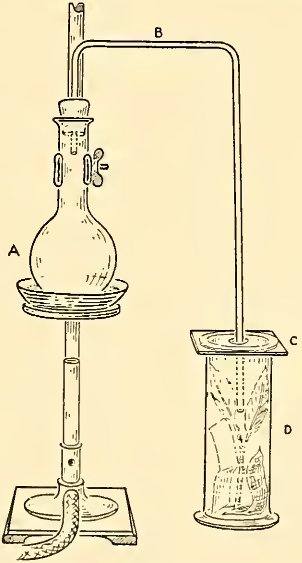


Fig. 41.—Preparation of chlorin.

89. Properties.—Physically considered, chlorin is a heavy, greenish yellow gas, with a penetrating, suffocating odor. Chlorin gas is poisonous. Chemically, it is an active element and has strong affinity for nearly all other elements. It readily combines with metals, forming chlorids, and light and heat are evolved during the reaction. Chlorin is an active bleaching reagent, as it changes the composition of vegetable dyes, thus destroying their color. Bleaching-powder is a mixture of calcium hypochlorite and calcium chlorid, and when used chlorin is liberated. Chlorin is also used as a disinfectant and as a germicide, for it is destructive to life, particularly to the lower forms. It is used extensively for both bleaching and disinfecting purposes. Chlorin takes no part directly in life processes, although its compounds, particularly sodium chlorid, are necessary as mineral food for animals.

90. The Chlorin Group of Elements.—Fluorin, chlorin, bromin, and iodin form a natural group of elements, known as the chlorin family. These elements are all closely related. They form similar acids with H, and similar salts with the metals. Some of the most important relationships and points of difference between members of the chlorin family will be observed from the following table:

Element.	At. wt.	Physical conditions.	H compound.	Na compound.
Fluorin........	19	Light gas	HFl	NaFl
Chlorin	35.45	Heavy gas	HCl	NaCl
Bromin........	79.95	Liquid	HBr	NaBr
Iodin	126.85	Solid	HI	NaI

91. Chlorids.—Combined with the metals, chlorin forms chlorids. As a class, the chlorids are quite stable compounds, inasmuch as chlorin has strong affinity for nearly all of the metals. The properties of the different chlorids vary with the metal with which the chlorin is combined. The chlorids do not take such a direct part in plant as in animal nutrition. When present in either soil or water in any appreciable amount, the soil is sterile and the water is not suitable for either drinking or irrigation purposes. Sodium chlorid is found in nature most abundantly of any of the chlorids.

Problem 1.—How much H_2SO_4 is required to combine with 2000 pounds NaCl in making HCl?

Problem 2.—How much HCl can be made from 2000 pounds of NaCl?

Problem 3.—How much Na_2SO_4 is produced when 2000 pounds NaCl are used for making HCl?

CHAPTER XII

Nitric Acid and Nitrogen Compounds

92. Occurrence.—Nitric acid does not occur in nature in a free state, but nitrates or salts of nitric acid are found as natural products. Since all normal nitrates are soluble in water, they are never found in great abundance in soils. In regions of scant rainfall, where climatic conditions have been favorable for the formation of nitrates, deposits of nitrate of soda are occasionally found. The nitrifying organisms of the soil, when supplied with food, moisture, suitable temperature, and other requisite conditions, produce nitrates which are utilized as food by plants. The process of nitrification which takes place in the soil, results in changing the inert and unavailable nitrogen to a soluble and available condition.

93. Preparation.—The same principle is applied in the preparation of nitric acid as in the preparation of hydrochloric acid. It is produced by the action of H_2SO_4 upon a salt; when a chlorid is used, hydrochloric acid is the product, and when a nitrate is used nitric acid is the product. The reaction when sodium nitrate is used is: $2NaNO_3 + H_2SO_4 = Na_2SO_4 + 2HNO_3$.

Experiment 15.—Preparation of nitric acid. Special care should be exercised by the student in the preparation of nitric acid, because if any is spilled on the hands it causes painful burns and wounds that are difficult to heal. Provided the student is careful and follows the directions given, there is no danger whatever in the preparation of this material. Arrange the apparatus as shown in Fig. 42. The delivery tube used in the preparation of NH_3 may be used for this experiment. If necessary, a brick or block may be placed under the cylinder. The delivery tube should pass into and nearly to the bottom of a test-tube which is immersed in cold water in the cylinder. Put 15 cc. concentrated sulfuric acid (H_2SO_4) and 10 grams of either sodium nitrate ($NaNO_3$) or potassium nitrate (KNO_3) into the flask and apply heat until about 4 or 5 cc. of HNO_3 is distilled and collected in the test-tube. Do not remove the flame unless the end of the delivery tube is above the liquid in the test-tube, otherwise the liquid will be drawn back into the flask.

Make the following tests with HNO_3. (1) Remove a drop of the acid by means of a glass tube, and apply it to either a piece of woolen cloth or silk. Observe the result. (2) Place a few drops of indigo solution in a test-tube containing 5 cc. of water, then add about 2 cc. of HNO_3. Observe the result. (3) Place a small piece of copper in the test-tube containing the remainder of the acid. Observe the result. If no reaction takes place, add a little water. Do not pour the contents of the flask into the sink or waste jars until cool, otherwise the hot acid coming in contact with cold water may cause spattering of the acid.

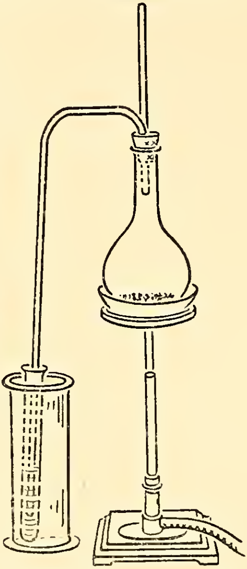


Fig. 42.—Preparation of nitric acid.

Questions. (1) Why was H_2SO_4 used in the preparation of this compound? (2) What material supplied the NO_3 radical? (3) Write the reaction which took place in the flask after heat was applied. (4) Is HNO_3 a solid, liquid, or gas? Why? (5) What caused the red fumes to be given off when the copper was added to the test-tube? (6) Does HNO_3 give off H when a metal is added to it? Why? (7) Why did the HNO_3 bleach the indigo solution? (8) Why is ordinary HNO_3 colored yellow? (9) Is HNO_3 an active or inert chemical? (10) What is a nitrate?

94. Properties.—When pure, nitric acid is a colorless liquid; the commercial acid has a yellow color because of the presence of oxids of nitrogen. Nitric acid is an active oxidizing reagent, and when metals, as copper and iron, are dissolved in it, brown fumes of NO_2 are given off because the hydrogen, as soon as liberated, is oxidized by the excess of acid and NO_2 is formed. $H + HNO_3 = H_2O + NO_2$. Nitric acid imparts a permanent yellow color to wool, silk, and all albuminous matter.

95. Importance.—In the laboratory, nitric acid is used as an oxidizing agent. It is used commercially in the dyeing of cloth, although it has a tendency to weaken the wool fibers. Salts of nitric acid are important because they are of so much value as plant food, and particularly in the manufacture of commercial fertilizer, where it supplies nitrogen. Potassium nitrate is used in the manufacture of gunpowder. Nitrates are of great importance in agriculture.

Ammonia

96. Occurrence.—Ammonium compounds are present in small amounts in the air, rain water, and in the soil, and are produced from decaying nitrogenous organic matter. The chief source of the ammonia which serves as the basis for the preparation of ammonium salts is the ammonia water obtained in the process of purifying illuminating gas made from soft coal. The nitrogen compounds of the coal form ammonia gas, NH_3, during the destructive distillation process.

97. Preparation.—In the laboratory, ammonia is usually prepared from ammonium chlorid by treatment with a strong base, as $Ca(OH)_2$. The reaction is:

$$2NH_4Cl + Ca(OH)_2 = CaCl_2 + 2NH_4OH.$$

Experiment 16.—Preparation of ammonia. Arrange apparatus as directed for the preparation of HCl (see Fig. 40). Into flask A, place 10 grams each of dry ammonium chlorid, NH_4Cl, and powdered calcium hydroxid, $Ca(OH)_2$, and 25 cc. water. Barium hydroxid, $Ba(OH)_2$, may be used in place of the $Ca(OH)_2$. When properly connected, apply heat to the sand-bath from eight to twelve minutes.

Tests for Ammonia. (1) Test the gas with wet litmus paper. Note the result. (2) Test the water in both Woulff bottles with litmus paper, and note the result. (3) In an evaporator place 5 cc. HCl and 10 cc. water. Disconnect the delivery tube from Woulff bottle C, and pass some of the fumes of the escaping gas over the acid in the evaporator. Avoid inhaling any of the gas. (4) Collect some of the gas in a test-tube and then place the test-tube inverted in a cylinder about one-third full of water. (5) Add 5 cc. of the NH_3 solution from either of the Woulff bottles to 5 cc. of a solution of alum. Note the result.

Questions. (1) What material supplied the NH_4 part of the NH_4OH? (2) What caused the gas to be liberated from these materials? (3) What chemical reaction took place in flask A after the heat was applied? (4) Why was water used in the Woulff bottle? (5) What did the water and the NH_3 gas form? (6) What reaction did the NH_3 gas and the NH_4OH give with the litmus paper? (7) Why was not this gas given off into the room? (8) Why was not NH_3 collected over water, like H, N, and O? (9) What caused the water to rise in the test-tube? (10) Why have you reason to believe that the NH_4OH caused a chemical reaction when added to the solution of alum?

98. Properties.—Ammonia is a colorless non-combustible pungent gas, which unites with water to form ammonium hydroxid, NH_4OH, a basic compound. It is completely soluble in water, from which it is easily liberated by heat. The gas can be reduced to liquid form by cold and pressure. Liquefied ammonia passes back to the gaseous condition with removal of the pressure, and in so doing, heat is absorbed from surrounding bodies. If this heat is absorbed from water, the temperature of the water is lowered sufficiently to produce ice. This property of liquefied ammonia is taken advantage of for the artificial production of ice, and for refrigerating purposes. The transportation of perishable food materials has been rendered possible by this method of refrigeration.

99. Uses.—In the laboratory, ammonium hydroxid is used extensively as a reagent for neutralizing acid solutions and precipitating insoluble hydroxids. Ammonium salts, when present in any appreciable amounts, are destructive to plants, $(NH_4)_2SO_4$ being less injurious than either NH_4Cl or $(NH_4)_2CO_3$. Hence $(NH_4)_2SO_4$ can be used in limited amounts as a fertilizer. Because of its being a volatile alkali, ammonia is valuable as a reagent for softening water.

In small amounts, so as to form very dilute solutions, the ammonium compounds serve as food for plants, supplying them with nitrogen which is used for producing, within the plant cells, complex nitrogenous compounds, as proteids. Ammonium compounds supply only one form of nitrogenous plant food.

100. Oxids of Nitrogen.—Nitrogen forms five compounds with oxygen :

N_2O nitrogen monoxid or nitrous oxid.
N_2O_2 nitrogen dioxid or nitric oxid.

N_2O_3 nitrogen trioxid or nitrous anhydrid.

N_2O_4 nitrogen tetroxid.

N_2O_5 nitrogen pentoxid or nitric anhydrid.

While the oxids of nitrogen do not serve as either plant or animal food, they are nevertheless important, and a study of these compounds is necessary in order to understand the subject of nitrogen.

101. Anhydrids.—An anhydrid is an oxid of an acid element, or the product which is left after the elements which form water are abstracted from an acid. SO_3 is sulfuric anhydrid, and is the product formed by abstracting H_2O from H_2SO_4. $H_2SO_4 = H_2O + SO_3$. N_2O_5 is nitric anhydrid, derived from two molecules of HNO_3. $2HNO_3 = H_2O + N_2O_5$.

Derive and name the anhydrids of the following acids: $2H_3PO_4$, H_2CO_3, H_2SiO_3, $2HNO_2$, H_2SO_3.

102. Law of Multiple Proportion.—When nitrogen and oxygen combine, the number of parts of nitrogen in the various compounds is constant, namely: 2, or 28 parts by weight in each compound. The number of parts of O is always a multiple of the first combination, N_2O; that is, it is either 2, 3, 4, or 5 times as much in the other compounds as in the first one. This is an example of the law of multiple proportion. When two elements combine in more than one way, the amount by weight of one of the elements remains constant in all the combinations, while the amount of the other element is always a multiple of the first combination.

The law of definite proportion holds true for each individual compound, while the law of multiple proportion applies to the entire series, and is a broader application of the law of definite proportion.

103. Importance of the Nitrogen Compounds.—The compounds of nitrogen, particularly nitrates and ammonium compounds, are of importance in agriculture as they serve as food for plants. They are difficult to retain in soils because of their solubility and the volatility of ammonia. In human and animal foods, the nitrogenous compounds are of importance in many ways; hence, in economic agriculture the compounds of nitrogen receive special consideration.

Problem 1.—How many pounds of HNO_3 can be produced from 100 pounds $NaNO_3$?

Problem 2.—How much H_2SO_4 is required when 100 pounds HNO_3 are made?

Problem 3.—How much NH_4OH can be produced from 10 pounds of NH_4Cl?

Problem 4.—What per cent. of NH_4OH is NH_3?

CHAPTER XIII

Phosphorus and Its Compounds

104. Occurrence.—Phosphorus is found in nature in combination with oxygen and other elements, forming phosphates, as $Ca_3(PO_4)_2$. It is never found in a free or uncombined condition. In soils, it is found in small amounts, and in many rocks and minerals, as apatite or phosphate rock, it is present in large amounts; it is also found in the ash of plants, and in animal bodies, particularly as a constituent of bones.

105. Preparation.—It is prepared from bones, which are first freed from organic matter by burning. The bone ash is treated with sulfuric acid, producing acid phosphates, which, when roasted with charcoal, liberate free phosphorus.

106. Properties.—There are two forms of phosphorus: the yellow and the red. Yellow phosphorus is a solid which ignites at a low temperature. Red phosphorus is an allotropic form of the element produced by heating the yellow variety in a sealed tube. Yellow phosphorus more readily combines with oxygen than does the red, and is kept under water to prevent contact with air.

107. Oxids of Phosphorus. — When phosphorus is burned in a current of oxygen or dry air, phosphorus pentoxid, P_2O_5, is obtained. This material is a white flocculent mass which readily dissolves in water, forming metaphosphoric acid. When phosphorus is burned in a limited amount of air, it forms phosphorus trioxid, P_2O_3, which after long standing dissolves in water, forming phosphorous acid. In fertilizer, soil, and food analysis, the amount of phosphorus is expressed in terms of P_2O_5.

108. Phosphoric Acid and Phosphates.—Ordinary phosphoric acid is produced by the action of H_2SO_4 upon bone ash.

$$3H_2SO_4 + Ca_3(PO_4)_2 = 2H_3PO_4 + 3CaSO_4.$$

Salts of ortho or ordinary phosphoric acid are the most common forms of the acid derivatives. Since this acid contains three replaceable H atoms, three salts are formed, as: Na_3PO_4, normal sodium phosphate; Na_2HPO_4, disodium phosphate; and NaH_2PO_4, monosodium phosphate. The three calcium salts of phosphoric acid are:

$CaH_4(PO_4)_2$, monocalcium phosphate.
$Ca_2H_2(PO_4)_2$, dicalcium phosphate.
$Ca_3(PO_4)_2$, tricalcium phosphate.

In addition to the ordinary phosphoric acid, there are other derivatives, as:

$H_3PO_4 = H_2O + HPO_3$ (metaphosphoric acid).
$2H_3PO_4 = H_2O + H_2P_2O_7$ (pyrophosphoric acid).

109. Phosphate Fertilizers.—In deposits of phosphate rock, the phosphoric acid is mainly in combination with calcium as $Ca_3(PO_4)_2$, and is of little value as plant food until it is treated with H_2SO_4 and converted into monocalcium phosphate, which is soluble and available as plant food. $Ca_3(PO_4)_2 + 2H_2SO_4 = CaH_4(PO_4)_2 + 2CaSO_4$. Large amounts of phosphates undergo this treatment in the manufacture of commercial fertilizers.

Experiment 17.—In a beaker on a sand-bath, dissolve 1/2 gram of bone-ash in 10 cc. dil. $HNO_3 + 20$ cc. H_2O; filter, and to the filtrate, while still warm, add 5 cc. ammonium molybdate, and then stir. Observe the precipitate, which is a compound of phosphoric acid, ammonium, and molybdenum.

Questions. (1) What was the solvent of the phosphoric acid? (2) Why was the solution boiled and filtered? (3) Describe the color and properties of the precipitate.

Experiment 18.—Dissolve 1/2 gram of sodium phosphate in 10 cc. distilled water, then add 10 cc. of a solution containing 1/2 gram $CaCl_2$. Observe the result. Write the reaction. Repeat this experiment, using $AlCl_3$ or alum in place of $CaCl_2$.

110. Compounds of Phosphorus.—Phosphorus forms a large number of compounds, as phosphates, metaphosphates, and pyrophosphates. It also combines with H, Cl, and I. With H it forms PH_3, phosphine, an analogous compound of NH_3. Phosphorus also enters into combination with C, H, N, O, and S, forming complex organic compounds, as nucleated proteids and lecithin. It is an element which has a wide range of combinations.

111. Importance of Phosphorus and Its Compounds.—The compounds of phosphorus, particularly the phosphates, are important in plant development, being essential forms of mineral food required for crop growth. Agriculturally considered, phosphorus is one of the most important of the elements. It is stored up in the seeds of grains, and in combination with the elements which form the organic compounds of plants, it takes an important part in animal nutrition. Compounds of phosphorus are used in the manufacture of matches, and as poison for insects. Phosphorus forms a large number of compounds both with the metals and with the elements which enter into the organic compounds of plant and animal bodies.

Problem 1.—How much P_2O_5 in a ton of bones, 80 per cent. $Ca_3(PO_4)_2$?

Problem 2.—How much would the P_2O_5 in a ton of $Ca_2H_2(PO_4)_2$ be worth at 5 cents per pound for the P_2O_5?

$$Ca_2H_2(PO_4)_2 = P_2O_5 + 2CaO + H_2O.$$

CHAPTER XIV

Sulfur and Its Compounds

112. **Occurrence.**—Sulfur is found free, and in combination with other elements; sulfids and sulfates are the compounds which occur the most abundantly. Sulfur is also found in small amounts, in combination with carbon, hydrogen, oxygen, and nitrogen, forming the organic compounds of plant and animal bodies.

113. **Preparation.**—When taken from the mines, sulfur is mixed with impurities, as sand and clay, which are partially removed by heating the sulfur, out of contact with the air, much in the same way that charcoal is produced. The crude sulfur is refined by vaporizing and condensing the volatile sulfur upon the surfaces of brick chambers, the product being known as flowers of sulfur. By drawing off the molten sulfur into wooden molds, roll sulfur, or brimstone, is formed.

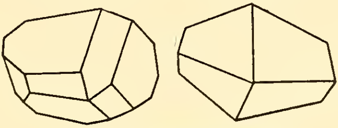


Fig. 43.—Crystals of sulfur.

114. **Properties.**—Like carbon and a few other elements, sulfur has a number of allotropic forms. It may assume either an amorphous or several crystalline forms. It melts at a low temperature, and when molten sulfur is poured into water, a rubber-like, amorphous mass is obtained. Sulfur combines with oxygen; and with the metals it forms sulfids.

115. Uses.—Sulfur is used in the preparation of sulfuric acid, in the production of vulcanized rubber, in the manufacture of matches and gunpowder, and for bleaching and disinfecting purposes. A small amount in the form of sulfates is necessary as plant food.

Experiment 19.—Properties of sulfur. Place 15 grams of sulfur in a test-tube and heat slowly until it is a thin, amber-colored liquid. As the heat increases, notice that it becomes darker until black, and so thick and viscid that it cannot be poured from the test-tube. Continue to apply heat until slightly lighter in color and again a liquid. Then pour the sulfur into an evaporating dish containing water, and, when cold, examine it and describe its properties. Examine the sulfur product or crystals left in the test-tube, and compare with the original sulfur, using a lens for the purpose.

Questions. (1) Are the crystals of sulfur formed by fusion like those of the original powdered form? (2) How is it possible for sulfur to assume different physical forms? (3) Is sulfur soluble in water? (4) What is a sulfate? Give the formula for one. (5) What is a sulfite? Give the formula for one. (6) What is a sulfid?

116. Sulfur Dioxid.—When sulfur is burned either in air or oxygen, SO_2, a colorless, suffocating, non-combustible gas is produced. SO_2 combines with water, forming H_2SO_3, sulfurous acid. Sulfur dioxid is used in bleaching and for disinfecting purposes, as it is alike destructive to organic coloring-matter and to germ life.

Experiment 20.—Sulfur dioxid. Fill the deflagration spoon half full of sulfur; ignite, and then lower into a small cylinder containing a piece of wet colored cloth and a piece of wet blue litmus paper. As soon as the sulfur ceases to burn, remove the spoon and cover the cylinder with a glass plate.

Questions. (1) What reaction does the SO_2 give with the litmus paper? (2) What effect does it have upon the cloth? (3) What does the SO_2 form with H_2O? (4) Is SO_2 a heavy or light gas? (5)

Is it a chemically active substance? (6) Why does it act as a bleaching agent? (7) Why is it valuable as a disinfectant?

117. Sulfuric Acid.—Sulfuric acid can not be produced from sulfates as HCl and HNO_3 were produced from their salts, because there is no acid or other material that can be used economically for the purpose. H_2SO_4 is made from its elements by the use of an oxidizing agent. The different steps in its production are:

(1) Burning of sulfur, or roasting of some ore, as pyrites, which contains sulfur. The S forms with O, SO_2.

(2) Union of SO_2 and H_2O, forming sulfurous acid, H_2SO_3.

(3) Oxidation of H_2SO_3 to form H_2SO_4. This is accomplished by the use of NO_2 reduced to NO, which in turn is capable of uniting with the oxygen of the air, re-forming NO_2. NO is used as a carrier of O; hence the oxygen of the air is used indirectly for the oxidation of H_2SO_3. The different reactions take place simultaneously in lead-lined chambers:

$$SO_2 + H_2O + NO_2 = H_2SO_4 + NO.$$
$$NO + O = NO_2.$$

Other and more complicated reactions also take place.

The crude acid is then concentrated and purified. Sulfuric acid is extensively used in industrial operations. There is scarcely a chemical product in the preparation of which H_2SO_4 has not been used either directly or indirectly. H_2SO_4 takes an important part in the manufacture of soda, which, in turn, is used for making glass; in the preparation of commercial fertilizers, and of many food products. The amount of sulfuric acid which a

L. of C.

country consumes is a fair index of the extent of its manufacturing industries.

118. Properties of H_2SO_4.—When pure it is a colorless, heavy, oily liquid. It has a strong affinity for water, with which it combines with evolution of heat. It will decompose organic materials containing C, H, and O, liberating the H_2O as water, with which it combines, while the carbon, which is partially oxidized, separates and blackens the acid. When sugar is acted upon by concentrated sulfuric acid, this change takes place. H_2SO_4 is used in the laboratory for drying gases, for drying the air in desiccators, and for oxidizing purposes, as in the determination of organic nitrogen in food materials. It is one of the most useful and extensively used of any of the reagents in the laboratory.

Experiment 21.—Make the following tests with some of the sulfuric acid from the reagent bottles: (1) Put 2 or 3 cc. H_2SO_4 into a test-tube; thrust a splinter of wood into it and leave it there for a few minutes. Then remove the splinter from the test-tube. Wash off the acid and examine the splinter. (2) Place in an evaporating dish 5 cc. water and 15 cc. H_2SO_4. Stir it with a small test-tube containing 1 or 2 cc. NH_4OH. Observe that the heat generated by the action of the H_2SO_4 and water, volatilizes some of the NH_3. (3) Put 10 cc. of water and 1 cc. of H_2SO_4 into a test-tube. Then add 2 or 3 cc. of barium chlorid, $BaCl_2$. Observe the result.

Questions. (1) Why is not H_2SO_4 made from sulfates? (2) Why is heat produced when water and H_2SO_4 are mixed? (3) What use was made of this heat in test No. 2? (4) What caused the precipitate when $BaCl_2$ was added? (5) Write the reaction. (6) What is the name of the product formed? (7) What are some of the uses of H_2SO_4? (8) How many kinds of salts does H_2SO_4

form? (9) Why is nitric oxid used in the manufacture of H_2SO_4? (10) What are the physical properties of H_2SO_4? (11) Of what agricultural value is H_2SO_4? (12) Does H_2SO_4 dissolve lead? (13) Why does commercial H_2SO_4 often appear dark-colored or deposit a fine white sediment?

119. Sulfates.—Sulfuric acid is a dibasic acid, and hence may form two series of salts, as $NaHSO_4$, primary sodium sulfate (acid sodium sulfate), and Na_2SO_4, secondary sodium sulfate (normal sodium sulfate). The sulfates of the metals form a large class of compounds which vary in chemical and physical properties according to the metal that is present. The sulfates as a class are fairly stable compounds; some, as sodium and potassium sulfates, are soluble; others, as calcium sulfate, are sparingly so while barium sulfate is one of the most insoluble substances in nature. Many of the sulfates contain water of crystallization. Some, as calcium and potassium sulfates, are valuable as fertilizers, while others, as copper sulfate, are used as fungicides.

120. Sulfids.—Sulfids are compounds of the metals with sulfur, as K_2S, FeS, and CuS. When a sulfid, as FeS, is treated with a dilute acid, H_2S, hydrogen sulfid, is liberated. $FeS + 2HCl = FeCl_2 + H_2S$.

The differences in solubility and other properties of the sulfids are taken advantage of in the separation and identification of the metals. H_2S is formed when albuminous matter, as the white of an egg, decays. It is also present as one of the gases given off from sewers. It is a poisonous, suffocating gas.

Experiment 22.—Hydrogen sulfid. (This experiment should be performed under the hood). Arrange the apparatus as shown in Fig. 44. The delivery tube and cork should fit tightly, and the delivery tube should pass into a test-tube containing 10 cc. of $Pb(NO_3)_2$ solution. Test-tubes containing 10 cc. respectively of NaCl, and $CuSO_4$ solutions should be conveniently at hand. Place 5 grams of pulverized FeS in the generating test-tube, add 10 cc. dilute HCl, and immediately connect with the delivery tube. After the gas has passed through the lead nitrate solution, for a couple of minutes, pass it through the sodium chlorid and copper sulfate solutions; then allow a little of the gas to escape into a cylinder containing water. Do not allow the free gas to escape in the room. With NaCl no insoluble sulfid is formed.

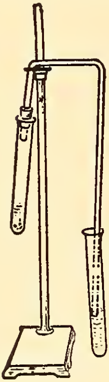


Fig. 44.—Hydrogen sulfid generator.

Questions. (1) What is the odor of the gas? (2) Write the equation for its production. (3) What was formed when the gas was passed into $Pb(NO_3)_2$? Write the reaction. (4) What was formed when the gas was passed through $Cu(NO_3)_2$? Write the reaction. (5) Is H_2S soluble in water? (6) When albumin decays, from what is the H_2S produced? (7) Why was no precipitate formed when the gas was passed through NaCl?

Problem 1.—How much H_2SO_4 can be made from one ton of sulfur?

Problem 2.—What per cent. of H_2SO_4 is SO_3?

Problem 3.—How much H_2SO_4 is required to neutralize 500 pounds NaOH?

CHAPTER XV

Silicon and Its Compounds

121. Occurrence.—Silicon is found in nature in combination with oxygen as silica, SiO_2; and with oxygen and the metals as silicates. It is never found free but always in combination with other elements. Next to oxygen it is the most abundant element found in nature. In the form of silicates it is the basis of the composition of nearly all rocks, and in the soil SiO_2 is found to the extent of from 60 to 90 per cent. It is present in the ash of plants and, to a slight extent, in animal bodies.

122. Preparation and Properties.—Silicon is separated from its compounds with difficulty. By treatment in an electric furnace, quartz or SiO_2 is reduced. Like carbon, silicon has crystalline and amorphous forms. Pure quartz, SiO_2, and other forms of silicon, are insoluble in nitric, hydrochloric, and sulfuric acids. When acted upon by hydrofluoric acid, silicon tetrafluorid, a gas is formed. $SiO_2 + 4HF = SiF_4 + 2H_2O$. HF is used extensively for the decomposition of silicates.

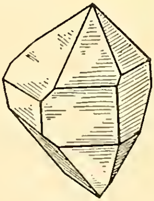


Fig. 45.
Quartz crystal.

123. Silicic Acid.—When SiO_2 is fused with the hydroxids or carbonates of potassium or sodium, potassium or sodium silicate is obtained:

$$SiO_2 + K_2CO_3 = K_2SiO_3 + CO_2.$$

$$SiO_2 + 4KOH = K_4SiO_4 + 2H_2O.$$

The silicates of potassium and sodium are soluble in water, and are commonly called water-glass. Some of the silicates are soluble in acids, but most of them are insoluble complex compounds which are difficult to decompose.

When K_4SiO_4 is treated with HCl, a gelatinous mass containing silicic acid is obtained: $K_4SiO_4 + 4HCl = H_4SiO_4 + 4KCl$.

H_4SiO_4 is normal silicic acid. Upon exposure to the air it loses a molecule of water and forms ordinary silicic acid, H_2SiO_3, which is decomposed by heat and in the presence of acids forms H_2O and SiO_2.

In addition to the two silicic acids, H_2SiO_3 and H_4SiO_4, there are other forms known as polysilicic acids as: $H_2Si_3O_7$, $H_4Si_3O_8$, and $H_2Si_2O_5$, obtained by removing water from the normal and ordinary silicic acid.

$$2H_2SiO_3 = H_2Si_2O_5 + H_2O.$$
$$3H_4SiO_4 = H_4Si_3O_8 + 4H_2O.$$

124. Dialysis.—In the preparation of silicic acid, the process known as dialysis is employed for dissolving and removing the impurities. Some substances, as NaCl and HCl, dissolve and readily pass through animal membrane; such substances are called crystalloids, while bodies like silicic acid, which do not penetrate animal membrane, or do so very slowly, are called colloids. The removal of the HCl from the solution containing the gelatinous silicic acid is accomplished by means of the dialyzer, Fig. 46. This property of materials, readily or

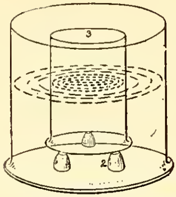


Fig. 46.—Dialyzer.

slowly to diffuse through animal membrane, is a physical characteristic, and is occasionally made use of for washing and separating compounds.

125. Silicates.—Since silicon forms such a variety of acids, the number of silicates found in nature is very large. The hydrogen atoms of silicic acid can be replaced with different metals, forming double salts, as $AlKSi_3O_8$, which is feldspar, or the double salt of trisilicic acid, $H_4Si_3O_8$. This renders the composition of the silicates exceedingly complex. Many of the silicates contain also water of hydration as part of the molecule; as aluminum silicate or pure clay, $Al_4(SiO_4)_3.H_2O$. Since rocks are composed mainly of silicates, and soils are formed from the decay of rocks, it follows that soils are practically a mechanical mixture of silicates with small amounts of other compounds. Hence, the importance of the subject of silicic acid and the silicates. Unfortunately the structure and composition of the silicates have not been determined as completely as of other salts and acids. Pure clay is aluminum silicate, formed from the disintegration of feldspar rock, a double silicate of potassium and aluminum. Mica, hornblende, and zeolites are all complex forms of silicates.

126. Importance of Compounds of Silicon.—The compounds of silicon, as silicon dioxid, SiO_2, and of the silicates, are used in the manufacture of glass, porcelain and brick. The element itself takes no direct part in animal or plant life, but indirectly is important, for it is in combination with many elements which serve as plant food. Some of the simpler and more soluble silicates are capable of being acted upon by decaying animal and vegetable matter and undergoing chemical changes which prepare them for plant food. Since silicon forms the principal acid element which enters into the composition of rocks, soils, building stones, glass, brick, and porcelain, and is associated with the elements in the soil which serve as plant food, it follows that it is an important element in industrial operations and in agriculture.

Experiment 23.—To about 5 cc. of sodium silicate in a test-tube add a few drops of HCl and observe the result. Then add NaOH and observe the result. Add more HCl, and evaporate the material to dryness in the evaporating dish. When cool, test the solubility of the residue in water.

Questions. (1) What was formed when HCl was added to sodium silicate? Write the reaction. (2) What was the appearance of the above product? (3) What effect did the NaOH have, and what was formed? (4) What was formed when the material was evaporated to dryness? (5) What can you say as to the solubility of the product?

Problem 1.—What per cent. of SiO_2 in clay, $Al_4(SiO_4)_3.H_2O$?

Problem 2.—How much silicic acid is formed when 10 grams of HCl act upon K_4SiO_4?

CHAPTER XVI

Oxids of Carbon, Carbonates, and Carbon Compounds

127. Carbon Dioxid.—Carbon dioxid is obtained from the combustion of carbon and also from the treatment of a carbonate with an acid. A carbonate is a salt of carbonic acid, M_2CO_3, in which M represents any monovalent metal, as K or Na. Calcium carbonate, $CaCO_3$, is the most abundant carbonate found in nature. When a carbonate is treated with an acid CO_2 is liberated, and a salt is formed, as

$$CaCO_3 + 2HCl = CaCl_2 + CO_2 + H_2O.$$

Experiment 24.—Preparation of carbon dioxid. Arrange the apparatus as for the preparation of hydrogen. Put 10 grams of marble, $CaCO_3$, into the Woulff bottle, and sufficient water to cover the end of the thistle tube. Fill 2 or 3 cylinders with water for collecting the gas, which is only slightly soluble in water, then add slowly, through the thistle tube, about 20 cc. concentrated HCl. Allow a little of the first gas generated to escape into the room and then collect 2 or 3 cylinders of CO_2. Remove the cylinders from the pneumatic trough and place them on the desk, right side up. Now remove the delivery tube from the pneumatic trough and allow the gas to pass into a test-tube containing about 10 cc. of clear lime water, $Ca(OH)_2$. If necessary, add through the thistle tube a little more acid to the generator. Observe the white precipitate formed in the test-tube. Let the gas pass through the lime water for several minutes, until the solution becomes clear. Now boil the solution and observe the reappearance of the white precipitate. Test some of the escaping gas with a burning splinter. Pour a receiver of the gas over a candle or a low gas flame, and observe the result. Thrust a burning splinter into a cylinder of

CO_2. Observe the result. Add 5 cc. water to the cylinder in which the splinter was placed, and then a little lime water; shake, and observe the result.

Questions. (1) Write the reaction for the preparation of CO_2. (2) What is a carbonate? (3) Is $CaCO_3$ soluble in pure water? (4) Is it soluble in water containing CO_2? (5) What caused the precipitate to form when the CO_2 gas was passed through the lime water? (6) What is this precipitate? Write the reaction. (7) What caused this precipitate to disappear when more gas was passed through the solution? (8) What caused it to reappear when the solution was boiled? (9) What caused the candle to be extinguished when a receiver of CO_2 was poured over the flame? (10) O is a supporter of combustion; CO_2 contains O; why does CO_2 not support combustion? (11) Is CO_2 a heavy or a light gas, and what tests indicate that it is heavy or light? (12) What other carbonate could be used for making CO_2? (13) What other acid could be used for making CO_2?

128. Carbon Monoxid.—Carbon monoxid is formed when carbon is only partially oxidized because of an insufficient supply of air. In a coal stove, for example, there is not a perfect supply of air in the interior of the burning mass; carbon monoxid is formed there and passes to the surface where it burns as a blue flame. If the draft is imperfect, a large amount of carbon monoxid is formed. When a coal stove gives off gas, the carbon monoxid is not oxidized, but is thrown off into the room. Carbon monoxid is a light, colorless, combustible, poisonous gas, and can be produced by subjecting highly heated carbon to the action of steam. The reaction is $C + H_2O = CO + 2H$. Both CO and H are combustible, and when they are enriched by some of the hydrocarbons, so as to introduce materials for producing light, when burned, they may be used for illuminating purposes, and the product is called water-gas. Carbon monoxid is produced in furnaces from the coke, which is mixed with ore, and in the smelting and refining of ores, carbon monoxid is an important reducing agent; in fact, it is the main reducing agent of the blast-furnace.

129. **Marsh Gas** (Methane, CH_4).—When vegetable matter decays under water, where the supply of air is incomplete, methane, CH_4, is one of the products formed. It is given off in bubbles from the surface of stagnant pools. It often collects in coal mines, and is there called fire-damp. CH_4 can be prepared in the laboratory in a number of ways, and is a colorless, combustible gas, which with air forms an explosive mixture.

130. **Hydrocarbons.**—A compound, as methane, composed of hydrogen and carbon, is called a hydrocarbon. There are a large number of such compounds, forming series in which the members differ from one another in composition by a definite number of C and H atoms, as methane, CH_4, and ethane, C_2H_6. The next member is propane, C_3H_8; CH_2 being the common difference between the members of this series. By oxidation, reduction, and substitution, in which a part of the H is replaced with equivalent radicals, a large number of derivatives, as alcohols, aldehydes, ethers and organic acids, are formed.

131. **Petroleum.**—Petroleum is an oily liquid obtained in some parts of the world by boring wells into the rock strata in which it is found as a natural product. It is a mechanical mixture of various liquid and solid hydro-

carbons, often accompanied with gaseous hydrocarbons. The hydrocarbons distilled off at a low temperature, ranging from 8° to 68° C., form the gasoline and benzine products, while those which distil between 175° and 215° C. form the various grades of kerosene. In the preparation of gasoline, benzine, and kerosene, the separation of the various grades of hydrocarbons is not complete; kerosene, for example, may contain traces of either gasoline or paraffin products. Kerosene should have a flashing-point not below 44° C. (111° F.), in order to render it safe for illuminating purposes. The flashing-point of kerosene may be approximately determined in the following way:

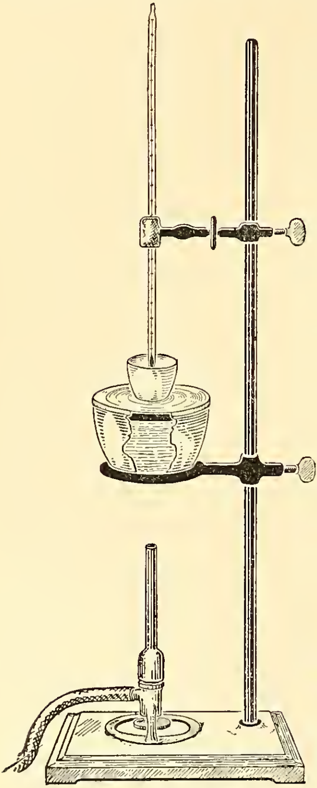


Fig. 47.—Testing kerosene.

Experiment 25.—Testing kerosene. Pour into a small porcelain crucible some kerosene; place the crucible upon a water-bath, and suspend a thermometer in the kerosene. Do not allow the water in the bath to come in contact with the crucible or the thermometer to touch the bottom. Cautiously heat the water until the thermometer registers 40° C., then remove the lamp and draw a lighted match across the surface of the kerosene. If it flashes, note its temperature; do not let it burn; should this occur, remove the thermometer and cover the crucible. If the kerosene does not flash, repeat the test and if necessary apply more heat until the flashing-point is reached. Calculate the corresponding temperature on the Fahrenheit scale.

132. Use of Gasoline.—Gasoline is perfectly safe for use as a fuel, provided a few simple precautions are observed: (1) Never use a gasoline stove when there is but little gasoline in the tank, because the last gas generated is mixed with air, and is liable to form an explosive mixture. (2) All joints and connections about the stove should be tight to prevent escape of gasoline into the air. Lack of care in this respect is the most frequent cause of fires. (3) The gasoline can should be well corked and stored in a cool place. (4) The stove should be kept clean, and no deposit of carbon should be allowed to collect upon the burners.

133. Illuminating Gas.—Illuminating gas is made from soft coal and petroleum by destructive distillation. The gases formed are washed and separated from ammonia and coal-tar, and consist of various hydrocarbons which are used for illuminating purposes. The coal, after being deprived of its gaseous products, is converted into coke, which bears the same relation to coal which charcoal bears to wood. The ammonia and coal-tar are recovered as by-products. Various coloring-matters are made from coal-tar.

If air is forced through gasoline in a confined chamber, or if gasoline is vaporized, it will burn like ordinary coal gas. Gasoline can be vaporized on a small scale, and machines suitable for the purpose are made for illuminating dwellings. Five gallons of gasoline will produce about 1000 feet of gas or vapor. The illuminating power of gas, and of flames in general, is expressed in terms of candle-power. A sixteen candle-power light is one that gives sixteen times as much light as a standard candle, composed of spermaceti, and burned at the rate of 120 grains per hour, the comparison being made by means of a photometer. In some localities, hydrocarbons, due to decomposition of organic matter, are given off from the earth as natural gas in amounts sufficient to be used for illuminating and fuel purposes.

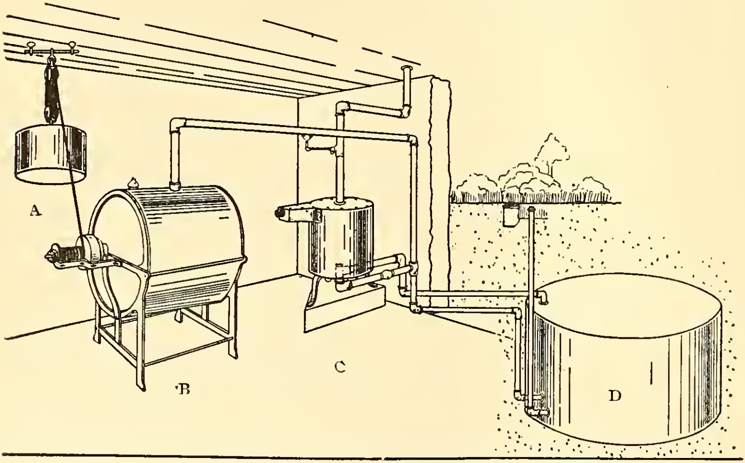


Fig. 48.—Illuminating gas plant for producing gas from gasoline. A, weight to air-pump B. D, carburetter or generating tank into which air is forced.

134. Mineral Oils.—The heavier products obtained in the distillation of petroleum, after the removal of the gasoline, benzine, and kerosene, are used for lubricating purposes, and are called mineral oils. They have a boiling-point from 250° to 350° C.

135. **Oil of Turpentine** ($C_{10}H_{16}$).—Oil of turpentine is obtained by distilling the resinous material which exudes from incisions in certain species of pines. Resin is obtained in the retorts. Oil of turpentine is inflammable, and dissolves readily in ether, alcohol, and naphtha. It is a valuable solvent, extensively used in the preparation of varnishes and paints, and as a solvent for caoutchouc. Turpentine belongs to the class of compounds known as essential oils.

136. **Creosote.**—When wood tar is distilled, various products are obtained which, after treatment with chemicals for purification, are called wood-tar creosote. This is a yellowish liquid with a smoky odor. It is a powerful antiseptic, and is the preservative employed in the preparation of "smoked meats," as hams and fish. It has no marked action on albuminous matter and in small amounts is not poisonous. Because of its antiseptic powers, wood creosote is used extensively for the preservation of wood, as it prevents decay. When some kinds of wood, as beech wood, are burned, the wood-tar condenses in the chimney.

137. **Benzine or Benzol** (C_6H_6).—When coal tar, obtained in the manufacture of illuminating gas, is subjected to fractional distillation, commercial products are obtained known as coal tar, naphtha, middle oil, heavy

oil, anthracene oil, and pitch or artificial asphaltum. The naphtha or light oil consists of a mixture of hydrocarbons, benzine being among the number. Benzine is extensively used as a solvent for fatty bodies. It is a very inflammable liquid.

138. Aliphatic and Aromatic Series of Compounds.—In organic chemistry benzine occupies an important position, as the direct treatment of benzine and its derivatives, produces the aromatic series of compounds, which form one of the two main divisions of the subject. The other is obtained from methane and its derivatives, and constitutes the aliphatic series. The alcohols, ethers, glycerides, fatty acids, organic acids, carbohydrates, and amids, are members of the aliphatic series, while essential oils, coloring-matters, and mixed nitrogenous compounds, are members of the aromatic series. In organic chemistry, a study is made of the formation, relationship, structure, and properties of all these compounds. Hence the importance of this branch of chemistry.

139. Carbon Disulfid.—With sulfur, carbon forms carbon disulfid, CS_2, a clear liquid with a characteristic odor. It readily burns and is easily vaporized. It is a solvent for fats, resins, sulfur, and iodin, and is used for the destruction of insects, particularly those infesting grains, and for killing small burrowing animals, as gophers.

140. Cyanids.—In the presence of metals carbon unites indirectly with nitrogen, forming cyanids as KCN. When mercuric cyanid is heated, cyanogen gas and metallic mercury are formed: $Hg(CN)_2 = Hg + 2CN$. Cyanogen and the cyanids are very poisonous. With H, cyanogen forms hydrocyanic acid, which is used for the destruction of scale insects and in the preparation of pigments.

141. Carbids.—With some of the metals, notably calcium, carbon forms carbids, as CaC_2, which is produced by the fusion of coke and limestone in electric furnaces. In the presence of water CaC_2 is decomposed, forming acetylene gas, C_2H_2, and calcium hydroxid.

$$CaC_2 + 2H_2O = C_2H_2 + Ca(OH)_2.$$

Acetylene generators are prepared for illuminating dwellings. Acetylene, like all gaseous hydrocarbons, as methane and benzine, forms explosive mixtures with oxygen. All illuminating gases should be dealt with as highly combustible and explosive materials.

142. Fuels.—There are three forms of fuel: (1) gas, (2) liquid, and (3) solid. Natural gas, coal gas, and gas generated from gasoline and naphtha, are the principal forms of gas fuel; kerosene, gasoline, and crude petroleum are liquid fuels, while coal, coke, lignite, peat, and wood are the chief forms of solid fuel. The composition of coal, coke, lignite, and peat, is discussed in Chapter V. Wood is composed largely of cellulose, and contains, when dry, about 50 per cent. carbon, 6 per cent. hydrogen, and 43 to 44 per cent. oxygen. Air-dried wood contains from 10 to 15 per cent. moisture. Different kinds of wood vary in density between quite wide limits; for example, a cord of dry pine weighs about 3000 pounds, while a cord of dry maple or other hard wood weighs from 4500 to 5000 pounds, or more. Hence the same volume (as a cord) of soft wood yields less total heat than a cord of hard wood, but a pound of the different kinds of wood gives nearly the same amount of heat. The amount of heat which a material produces when burned is measured in the calorimeter, and is given in terms of calories or heat units. The presence of water in fuels lowers their caloric value, because it requires a definite amount of heat to evaporate and expel as steam the moisture before combustion can take place.

143. Caloric Value of Fuels (Comparison made on basis of equivalent weights).

	Calories. Perfectly dry.	Calories. With water.	Per cent. of water.
Hard coal	9160	8690	2.63
Soft coal	7664	7128	5.02
Pine (red)	5997	5155	13.83
Cedar	5974	5031	14.09
Maple	5978	5117	12.49
Birch	5978	4758	21.70

144. Foods.—The materials used as human and animal foods are mechanical mixtures of various organic compounds, as starch, sugar, fat, albumin, etc., together with various mineral salts. The composition of the organic compounds of foods forms a part of the study of organic chemistry, while their economic value and the uses made of them by the body, are studied in physiological chemistry. Knowledge in regard to the composition and uses of foods, particularly of human foods, is somewhat limited, although along this line, many facts and laws of economic and sanitary importance have been discovered. The subject of foods is treated more fully in the chapters relating to the chemistry of foods.

Vegetable foods and fuels are alike in chemcal composition, and serve somewhat the same functions, but in different ways. Food is used as fuel by the body, and also for the renewal of old and the production of new tissues. The heat produced from food is transformed into muscular and other forms of energy; the heat from the combustion of fuel is converted into chemical energy, which is utilized for mechanical purposes.

145. Production of Organic Compounds in Plants.— The carbon dioxid of the air is the source of the carbon used by plants for the production of the various organic compounds found in vegetable substances, and since about 50 per cent. of the ash-free tissue of plants is carbon, it follows that the carbon dioxid of the air is an important factor in plant growth. Hydrogen and oxygen are obtained from the water of the soil which is received from the air. The production of the various organic com-

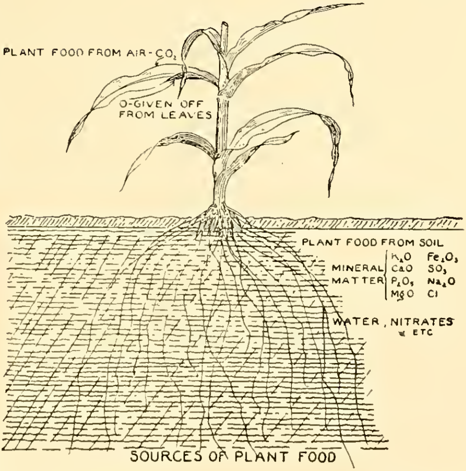

PLANT FOOD FROM AIR-CO_2
O-GIVEN OFF FROM LEAVES
PLANT FOOD FROM SOIL
MINERAL MATTER
K_2O Fe_2O_3
CaO SO_3
P_2O_5 Na_2O
MgO Cl
WATER, NITRATES & ETC
SOURCES OF PLANT FOOD

Fig. 49.—Production of organic compounds in plants, showing sources of plant food.

pounds of plants takes place in the cells of the leaves, and is the result of chemical changes induced by life processes. In order to promote cell activity, sunlight and a suitable temperature are necessary. The sun's rays take an important part in promoting chemical changes in the leaves of plants. In addition to carbon dioxid, water, heat, and sunlight, various mineral elements in the form of compounds of potassium, calcium, phosphorus, nitrogen, iron, magnesia, sulfur, and possibly of a few others are required as plant food. Without these essential elements and requisite conditions, the growth of crops cannot take place. It often happens that soils are unproductive because of the absence, in available form, of some of the elements essential for plant life. The production in the leaves of plants of the various organic compounds, as cellulose, starch, sugar, fat, albumin, etc., and a few of the complex chemical changes which take place, have been studied.

146. Decay of Organic Compounds.—All organic compounds, particularly those found in the tissues of plants and used as food, are subject to chemical change commonly called decay. Such change is nearly always produced as the result either of the action of organized ferments, or of the chemical products known as chemical or soluble ferments. Fermentation changes and decay take place whenever cell activity becomes feeble or ceases; then the material becomes food for micro-organisms. Many chemical changes take place as the result of fermentation; some of these are necessary in plant and animal nutrition. If the chemical changes, coordinate with fermentation, are uninterrupted, the organic materials are decomposed until carbon dioxid, water, ammonia gas, and hydrogen sulfid are obtained as the final products. When such changes take place, the mineral matter combined and associated with the organic matter is left as non-volatile products. In economic agriculture, it is the aim to conserve and return to the soil these essential elements, as nitrogen, potassium, phosphorus, and calcium, which are frequently unavailable or present in scant amounts in soils, so that the fertility will not be impaired. The elements present in plant and animal bodies pass through a cycle of chemical changes; they are never lost to nature, but appear in different chemical compounds, as exemplified by the law of indestructibility of matter.

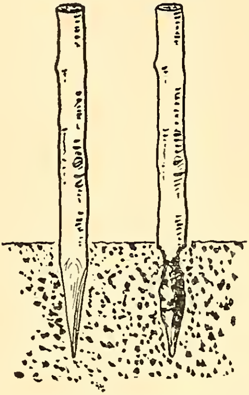


Fig. 50.—Decay of wood.

A. Elements of plant growth in soil and air.

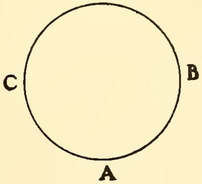


Fig. 51.

B. Elements from soil and air elaborated into plant tissue.

C. Elements in plant tissue elaborated into animal tissue.

The elements in either plant or animal bodies may pass back to A, and then pass again through the same cycle of chemical changes.

CHAPTER XVII

Writing Equations

147. Importance.—A chemical equation expresses concisely the changes which take place when two or more compounds are brought together so as to react, or when a material is acted upon by any agent which causes a chemical change. When chemical equations are understood by the student, they are of great assistance, as they necessitate a knowledge of the laws of valence, of the power of replacement, and of the properties of the elements and their compounds.

148. Common Errors in Writing Equations.—Some of the more common errors in writing equations are:

(1). Failure to use correct formulas.

(2). Failure to use the correct number of parts of compounds, radicals, or elements.

(3). Failure properly to balance the equation.

(4). Failure to form reasonable compounds or products.

If the correct formula, or the right number of molecules is not used, the equation is incorrect, it cannot be balanced, and the principle represented by the sign of equality is violated. There should be as many atoms of an element on one side of an equation as on the other. In order properly to balance an equation, as many molecules of the compounds on the left of the equation should be taken as are needed to satisfy the valences of the reacting elements and radicals. In the equation

$$AgNO_3 + HCl = AgCl + HNO_3,$$

only one molecule each of $AgNO_3$ and HCl is necessary, because all of these elements and radicals are monovalent. A simple exchange takes place in which the H of the acid is replaced by the metal Ag. If the elements H and Ag were to exchange places, they would occupy, after the exchange, the positions shown on the right-hand side of the equation. This exchange is represented graphically in Fig. 52; A represents the order before, and B after the reaction. Blocks of wood marked to represent the elements and radicals can be used, the block marked H being replaced by the equivalent block marked Ag. When difficulty is experienced in writing chemical equations, this method of illustration will be found helpful.

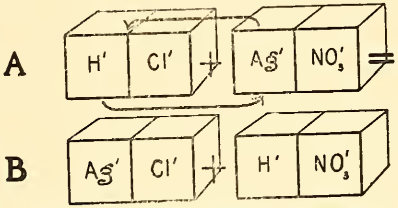


Fig. 52.—Graphic illustration of a chemical reaction.

In an equation as

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl,$$

where both monovalent and bivalent elements and radicals are present, it is necessary to take two molecules of NaCl because there are two H atoms to be replaced. H and Na have the same valence, *viz.*, 1, and SO_4 has a valence of 2. In order to obtain two atoms of Na, it is necessary to take 2NaCl; then two atoms of Na replace two of H. The products are Na_2SO_4 and 2HCl. SO_4 is a radical with a valence of 2 and requires 2Na atoms in order to form a compound. A similar reaction is represented graphically by the use of blocks in Fig. 53. A represents the arrangement before, and B the arrangement after the reaction. Observe that in this equation there is the same number of atoms of each element on each side of the equation. After writing an equation the student should always observe whether or not it is properly balanced, and that reasonable products are formed. The valences of the elements and radicals are given in Sections 15 and 77.

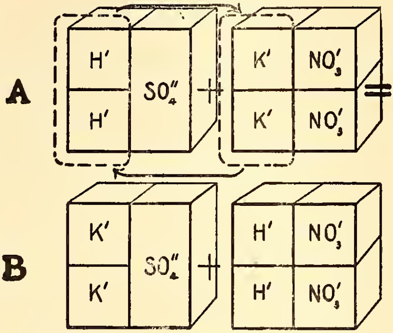


Fig. 53.—Graphic illustration of a chemical reaction.

There are always as many parts by weight of the elements on one side of an equation as on the other. That is, the sum of the weights of the atoms and molecules on one side is equal to the sum of those on the other, as:

$2NaCl$ +	H_2SO_4 =	$2HCl$ +	Na_2SO_4.
$2Na = 46$	$2H = 2$	$2H = 2$	$2Na = 46$
$2Cl = 71$	$S = 32$	$2Cl = 71$	$S = 32$
——	$4O = 64$	——	$4O = 64$
117	——	73	——
	98		142

$117 + 98 = 215.$ $73 + 142 = 215.$

In the case of trivalent and bivalent elements and radicals, as in the reaction between H_3PO_4 and $Ca(OH)_2$, it is necessary to take $2H_3PO_4$ and $3Ca(OH)_2$, in order to make the equation balance. The Ca and H atoms exchange places; there are three H atoms to be replaced. Ca has a valence of 2; 1 Ca cannot replace 3H, but $6H(2H_3)$ can be replaced by 3Ca, because $2H_3$ has a total valence of 6 and so has 3Ca.

$$2H_3PO_4 + 3Ca(OH)_2 = Ca_3(PO_4)_2 + 6H_2O.$$

3Ca atoms replace the $2H_3$ and form $Ca_3(PO_4)_2$, a balanced compound, because PO_4 is a radical having a valence of 3, and if taken twice its total valence is 6, with which 3 Ca atoms can combine. The remaining H and O atoms form $6H_2O$.

149. Impossible Reactions.—Not all chemical compounds when brought together give a chemical reaction. Whether or not a reaction takes place can be determined only after a careful study of the elements and their properties; this often involves a more exhaustive knowledge of chemistry than can be obtained from an elementary study of the subject.

In the case of $BaSO_4 + 2HCl$, no reaction can take place, although an apparently correct reaction can be written:

$$BaSO_4 + 2HCl = BaCl_2 + H_2SO_4.$$

This is because $BaSO_4$ and HCl are the products of the reaction

$$BaCl_2 + H_2SO_4 = BaSO_4 + 2HCl.$$

In the equations given at the end of this chapter a reaction takes place in each case.

150. A Knowledge of Reacting Compounds and Products Necessary.—In order that the writing of chemical equations may become more than a mere mechanical operation, the student should study the character and properties of the compounds used and of the products formed. If one of the compounds is an acid and the other a base, the subject of neutralization is illustrated. If one of the compounds is an acid and the other a metal, the replacement of the H of the acid occurs. Should one of the compounds be an acid and the other a salt, an equivalent amount of the H is replaced by the metal or basic element of the salt. Other principles and laws should be observed by the student in writing equations. The character of the compounds, as acid, base, or salt, with their names, forms a part of equation work, which is an essential feature of elementary chemistry.

151. Equations for Class Room Work.—The student should write the following equations:

1. $CaCl_2 + Na_2CO_3 =$
2. $CaCl_2 + Na_2SO_4 =$
3. $Ca(OH)_2 + H_2SO_4 =$
4. $CaCO_3 + HCl =$
5. $MgCO_3 + HCl =$
6. $KNO_3 + H_2SO_4 =$
7. $CaCl_2 + Na_3(PO_4) =$
8. $Pb(NO_3)_2 + 2HCl =$
9. $AlCl_3 + NH_4OH =$
10. $Ba(OH)_2 + H_2SO_4 =$
11. $BaCl_2 + H_2SO_4 =$
12. $Pb(NO_3)_2 + H_2SO_4 =$

13. $Na_2CO_3 + H_2SO_4 =$
14. $Na_3PO_4 + H_2SO_4 =$
15. $Ca(OH)_2 + Na_2SO_4 =$
16. $Fe(OH)_3 + H_2SO_4 =$
17. $(NH_4)_2SO_4 + Ca(OH)_2 =$
18. $NH_4NO_3 + H_2SO_4 =$
19. $(NH_4)_2CO_3 + HCl =$
20. $NH_4Cl + H_2SO_4 =$
21. $NH_4Cl + Ca(OH)_2 =$
22. $NH_4Cl + NaOH =$
23. $NH_4Cl + Ba(OH)_2 =$
24. $NH_4NO_3 + Ca(OH)_2 =$
25. $NH_4OH + HCl =$
26. $NH_4NO_3 + KOH =$
27. $FeCl_2 + NaOH =$
28. $FeCl_2 + NH_4OH =$
29. $AgCl + NaOH =$
30. $Na_2CO_3 + Ba(OH)_2 =$
31. $Na_2CO_3 + HCl =$
32. $NaOH + FeCl_2 =$
33. $AgNO_3 + NaCl =$
34. $AgNO_3 + HCl =$
35. $Ca_3(PO_4)_2 + 3H_2SO_4 =$
36. $CaCO_3 + \text{heat} =$
37. $CaO + CO_2 =$
38. $Ca(OH)_2 + CO_2 =$
39. $K + H_2O =$
40. $AlK(SO_4)_2 + 4KOH =$
41. $AlNH_4(SO_4)_2 + NH_4OH =$
42. $CaCl_2 + (NH_4)_2CO_3 =$

43. $CaCl_2 + H_2SO_4 =$
44. $Na_2SiO_3 + HCl =$
45. $CaSiO_3 + Na_2CO_3 =$
46. $C + CuO =$
47. $3Cu + 8HNO_3 =$
48. $C_6H_{10}O_5 + 12O =$
49. $AlCl_3 + H_3PO_4 =$
50. $AlCl_3 + NH_4OH =$

CHAPTER XVIII

Potassium, Sodium, and Their Compounds

152. Occurrence of Potassium.—Potassium is found in nature largely in combination with silicon and other elements, forming silicates, which undergo slow disintegration with liberation of potassium salts which become food for plants. Potassium is present in the ash of all plants and food materials and is one of the elements required by crops. In some "alkali" soils, small amounts are found in the form of potassium salts. Deposits of various double salts of potassium, supposed to have been formed by crystallization from sea-water, are found at Stassfurt in Prussia, and are commonly known as Stassfurt salts. These are the chief source of the potassium compounds, some of which are extensively used in the preparation of fertilizer.

The element potassium is most typical of all the base elements as a class. It is never found in nature in a free state, but always in combination with other elements from which it is separated with difficulty. It is a light substance with a metallic luster, and in the laboratory is kept out of contact with air and water, with which it readily reacts.

153. Potassium Hydroxid.—This is a strong basic compound extensively used in the laboratory and in manufacturing operations. It is prepared by treating K_2CO_3 with $Ca(OH)_2$, the reaction being $K_2CO_3 + Ca(OH)_2 = CaCO_3 + 2KOH$. $CaCO_3$ is insoluble and can be separated by filtering from KOH which is soluble.

KOH, commonly called caustic potash, is a white, brittle substance which readily absorbs moisture and carbon dioxid from the air.

Experiment 26.—Preparation of KOH. Dissolve 5 grams potassium carbonate, K_2CO_3, in an evaporating dish containing 15 cc. of water. Add a mixture of 3 grams $Ba(OH)_2$ and 10 cc. of water. Heat on the sand-bath for five minutes. Filter off the solution. Observe the precipitate. Evaporate some of the solution to dryness in the evaporator.

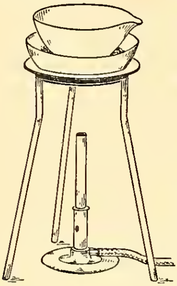


Fig. 54.—Preparation of KOH.

Questions. (1) Write the reaction which takes place between K_2CO_3 and $Ba(OH)_2$. (2) What is the insoluble white material left on the filter-paper? (3) Is the KOH soluble or insoluble? (4) What other material could be used in place of $Ba(OH)_2$? (5) If Na_2CO_3 were used instead of K_2CO_3, what product would be formed? Write the reaction. (6) What reaction does K_2CO_3 give with litmus paper? (7) What reaction does NaOH give? (8) What are some of the uses made of KOH? (9) What would result if the KOH in the evaporator were left exposed to the air for a day or so?

154. Potassium Nitrate.—This salt is found in small amounts in fertile soils where conditions have been favorable for nitrification processes (see Section 92). It is extensively used in the arts, and is prepared from sodium nitrate deposits which occur as natural products known as Chile saltpeter. It is an oxidizing agent and is one of the ingredients of gunpowder which is a mixture of sulfur, carbon and potassium nitrate. Potassium nitrate, in small amounts, is occasionally used for the preservation of meats.

155. Potassium Carbonate.—When wood ashes are leached, potassium carbonate is the chief alkaline salt extracted, and this product is called potash which, by the removal of impurities, furnishes pure K_2CO_3. Potassium carbonate is prepared from the chlorid in the same way that sodium carbonate is prepared from its chlorid as explained in Section 162.

156. Potassium Chlorate is prepared by the action of chlorin gas upon potassium hydrate. It is used in the laboratory as an oxidizing agent, and for the preparation of oxygen. It is one of the ingredients of safety matches.

157. Potassium Sulfate is found in nature in the form of double salts, in the Stassfurt deposits and elsewhere. It is employed in the preparation of alum and other compounds. There are two sulfates of potassium : primary on acid potassium sulfate, $KHSO_4$, and secondary or normal potassium sulfate, K_2SO_4.

158. Miscellaneous Potassium Salts.—Potassium forms a large number of salts, as KCl, KBr, KF, KI, KCN, K_2O, K_2S, KNO_2, many of which are very valuable in medicine, in the arts as photography, and in the laboratory for the preparation of other compounds. The salts of potassium vary in chemical and physical properties according to the acid elements or radicals with which the potassium is combined. All of the common salts of potassium, except the double silicates, are soluble in water.

159. Occurrence of Sodium.—Sodium and potassium are very much alike in general properties, and form analogous salts and compounds. Sodium is not as strong a type of basic element as is potassium and can be separated from its compounds more readily, although it is not easily replaced by other elements or by simple chemical forces. Sodium and its compounds are less expensive than potassium and its compounds. In industrial operations, sodium salts are more extensively used, but to the agricultural student, potassium is of greater importance because sodium takes little or no part in plant nutrition. In animal life, however, sodium chlorid plays an important rôle. Sodium is never found in nature in a free state, sodium chlorid being one of the most abundant of its salts. Sodium is also found as silicates and in small amounts in other forms.

160. Sodium Chlorid.—Extensive deposits of this salt are found in nature ; in some places it is mined, the product being known as rock salt. It is present in sea-water in large amounts from which it is occasionally obtained in an impure form along with a large number of other salts. When pure, sodium chlorid forms colorless, transparent cubes. A large amount of commercial salt is obtained by the evaporation of water from salt springs. In some localities, water is forced into and through deposits of salt which it dissolves and is then pumped out and evaporated to dryness. Sodium chlorid is extensively used for the preparation of sodium and other compounds as hydrochloric acid. It is not found to any appreciable extent in ordinary agricultural plants, but in some alkali plants there are quite large amounts. When sodium chlorid contains impurities, as calcium chlorid and lime salts, the material readily absorbs moisture from the air while other compounds cause it to form lumps and hard cakes. Hence a salt which readily absorbs moisture or forms hard lumps is not a pure one. Sodium chlorid takes but little or no part in plant life but is necessary for animal life.

161. Sodium Nitrate.—Extensive deposits of sodium nitrate are found in Peru, Chile, and other South American countries. It is commonly called Chile saltpeter. As stated in Section 154, it is extensively used for the preparation of potassium nitrate and in the manufacture of nitric acid and commercial fertilizers. Sodium nitrate is commercially and agriculturally an important product. The value of nitrogen in fertilizers is usually based upon its selling price. Small amounts of this salt formed by the process of nitrification are found in soils of high fertility. Because of its solubility, however, sodium nitrate never accumulates in soils.

162. Sodium Carbonate.—Commercially, this salt is known as soda and is one of the most useful chemicals manufactured. It is extensively used in the making of soap and glass, and in other commercial operations. It is prepared by two processes, one known as the Le Blanc process, and the other as the ammonia or Solvay process. By the Le Blanc process, it is prepared from sodium chlorid treated with sulfuric acid which produces Na_2SO_4.

$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl.$$

The sodium sulfate is heated with charcoal which produces sodium sulfid.

$$Na_2SO_4 + 2C = Na_2S + 2CO_2.$$

When heated with calcium carbonate, sodium sulfid forms sodium carbonate and calcium sulfid, the latter product being insoluble in water while sodium carbonate is soluble in water, and hence is readily separated by filtration. The process of manufacture usually consists in mixing coal and calcium carbonate with sodium sulfate, the product being known as crude soda which is refined and from which calcined and crystallized soda are obtained.

In the Solvay process, $(NH_4)_2CO_3$ is employed, which forms, with sodium chlorid, $HNaCO_3$ which when heated yields Na_2CO_3, CO_2 and H_2O.

163. Sodium Hydroxid.—This base is prepared in the same way as KOH; Na_2CO_3 being used in place of K_2CO_3. NaOH is extensively used in the manufacture of soaps.

164. Sodium Phosphates.—Sodium forms three phosphates: primary sodium phosphate, secondary sodium phosphate, $NaHPO_4$, and tertiary or normal sodium phosphate, Na_3PO_4. Phosphates of soda are not found to any appreciable extent in soils because phosphoric acid forms, with iron, alumina and calcium which are always present, insoluble compounds.

165. Miscellaneous Sodium Salts.—Like potassium, sodium forms a large number of salts as Na_2SO_4, $NaHSO_4$, NaBr, NaCN, Na_2S and Na_2O. Sodium compounds are all soluble except the silicates and a few of the more complex salts.

As previously stated, salts of sodium are similar to the corresponding salts of potassium. The sodium compounds are among the most useful and important compounds found in nature.

Experiment 27.—Fill a cylinder about two-thirds full of water, and place upon the surface of the water a piece of Na about half as large as a pea, using forceps for the purpose. If there is no small piece of Na in the bottle, one may be cut by means of a knife without removing the Na from the naphtha which surrounds it. Observe the result when the Na is placed upon the water. The apparatus can be arranged and the escaping hydrogen collected as shown in Fig. 55. (The test-tube should be filled with water and the Na wrapped in a piece of filter-paper.)

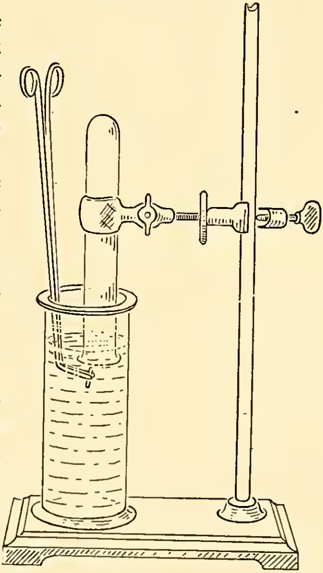


Fig. 55.—Decomposition of water by the use of sodium.

Questions. (1) Give the reaction which takes place between the Na and the H_2O. (2) What gas is liberated? (3) What becomes of the Na in the experiment? (4) Is this product soluble or insoluble? (5) Test the liquid in the cylinder with litmus paper and observe the result. (6) Is Na a light or heavy metal? Why? (7) Is it active or inert? (8) Why is Na always kept in a bottle containing naphtha or kerosene? (9) Since Na is found in nature and its compounds are present largely in sea-water, why does not this element, Na, decompose sea-water as it did the water in this experiment.

CHAPTER XIX

Calcium, Magnesium, and Their Compounds

166. Occurrence of Calcium.—This element is found widely distributed in nature in the form of calcium carbonate, $CaCO_3$, calcium phosphate, $Ca_3(PO_4)_2$, and calcium sulfate, $CaSO_4$, and is a yellowish metal which readily oxidizes and decomposes water. It enters into the composition of both plant and animal bodies and takes an important part in life processes. Its compounds are useful in the industries, lime, cement, and mortar being some of the forms in which it is employed. Calcium is not easily separated from its compounds.

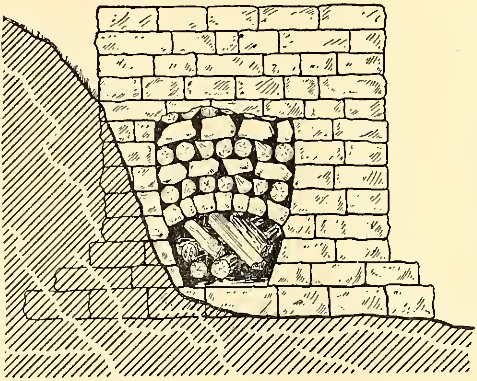


Fig. 56. Section of lime kiln.

167. Calcium Carbonate.—This compound, in the form of limestone and marble, is found quite extensively. It is soluble to a slight extent in water charged with carbon dioxid, and hence many waters, as stated in Section 65, owe their hardness to its presence. Calcium carbonate is used principally for the preparation of quicklime, in the manufacture of glass and in the refining of some of the metals where it is employed as a flux.

168. Calcium Oxid.—When calcium carbonate is subjected to heat, as in lime kilns or specially constructed furnaces, the carbon dioxid is separated and the oxid obtained. Layers of limestone and wood are placed alternately in the lime kiln, as shown in Fig. 56; the combustion of the wood furnishes the necessary heat for the decomposition of the carbonate. Calcium oxid or quicklime readily combines with both the carbon dioxid and moisture of the air, forming air-slaked lime. During this process of slaking, there is a material increase in volume often resulting in the bursting of the barrels in which the lime is stored. Calcium oxid is used for the preparation of calcium hydroxid and mortar.

169. Calcium Hydroxid.—When water is added to calcium oxid or quicklime, the material undergoes the slaking process and calcium hydroxid, $Ca(OH)_2$, is produced.

$$CaO + H_2O = Ca(OH)_2.$$

Calcium hydroxid or slaked lime readily absorbs carbon dioxid from the air and forms calcium carbonate. $Ca(OH)_2$ is somewhat soluble in water, forming what is commonly called lime water. When carbon dioxid is passed into lime water, the solution becomes turbid, due to the formation of $CaCO_3$. This reaction furnishes a means

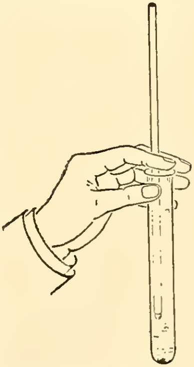


Fig. 57.

of testing for carbon dioxid. If a small amount of any material supposed to contain carbonates is placed in a test-tube along with a little water, and then a small glass tube or loop-tube containing a few drops of lime water is inserted in the test-tube, after the gas is liberated by hydrochloric acid, the drop of lime water becomes turbid, due to the formation of $CaCO_3$ (see Fig. 57).

170. Calcium Sulfate.—Deposits of this salt known as gypsum, $CaSO_4.2H_2O$, are found abundantly in some localities. Gypsum or land plaster is used as a fertilizer and also for the preparation of plaster of Paris. The "setting" of plaster of Paris is due to the fact that when the water of crystallization is expelled, the substance is again capable of taking up water, expanding, and forming a hard mass.

171. Calcium Chlorid.—This salt is not found in nature to any appreciable extent. It is employed in the laboratory in desiccators and for the drying of gases.

172. Bleaching-Powder.—This material is made by passing chlorin into a solution of lime water. The chlorin is held in chemical combination, forming calcium hypochlorite, $Ca(ClO)_2$, which readily gives up its chlorin and is extensively used for bleaching and disinfecting purposes as explained in Section 89.

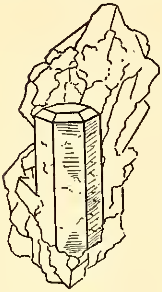


Fig. 58. Apatite rock.

173. Calcium Phosphate. — Deposits of this material are found in nature in various physical forms as soft phosphate, and in crystalline form, as apatite rock, see Fig. 58. Calcium phosphate is extensively used for the preparation of commercial fertilizers as explained in Section 109.

174. **Mortar.**—When quicklime is slaked and mixed with sand, it forms at first a mechanical mixture. When it is placed upon the walls of buildings, a chemical change, known as the hardening or setting process, takes place. When this change occurs, the moisture is expelled and the carbon dioxid of the air changes the calcium hydroxid to calcium carbonate. In the slaking of lime and setting of mortar, the following reactions take place:

$$(1)\quad CaO + H_2O = Ca(OH)_2.$$

$$(2)\quad Ca(OH)_2 + CO_2 = CaCO_3.$$

When magnesium carbonate and aluminum silicate are present, forming a part of the composition of the original lime rock, hydraulic cement is produced which has the property of setting under water.

Experiment 28.—Testing quality of lime. Place about 40 grams of lime, CaO, in an evaporating dish and moisten with water warmed to about 35° C. Note the reaction. Good lime readily undergoes the slaking process. Place some of the slaked lime in a bottle, add about 100 cc. of distilled water, shake vigorously and leave the lime in contact with the water for four hours or longer, then filter some of the solution of lime water, and test it by forcing respired air through it as explained in Experiment 24.

Place about one-half gram of the slaked lime in a test-tube, add 10 cc. of water and then a few drops of HCl. When action ceases, add more HCl, a little at a time, and heat. The material which fails to dissolve usually consists of insoluble silica and clay. Lime of a high degree of purity contains less than 10 per cent. of acid-insoluble impurities.

Questions. (1) Was any heat evolved when the lime was slaked? Why? (2) Did any noticeable change take place in volume during slaking? (3) What is lime water? (4) What is the object of forcing respired air through the lime water of the test-tube? (5) Write the reaction which took place. (6) Write the reaction when HCl was added to $Ca(OH)_2$.

175. Glass.—Glass is a double silicate of calcium and sodium, produced by fusing pure sand, sodium carbonate and lime. When potassium carbonate is substituted for the sodium salt, Bohemian or hard glass is prepared. Other kinds and varieties of glass are made by introducing other substances and giving different mechanical treatment to the material during its preparation.

176. Occurrence of Magnesia.—This element does not occur as extensively in nature as calcium which it resembles in many respects. It is found associated mainly with calcium in the mineral dolomite, a double carbonate of calcium and magnesium. Magnesium is separated from its compounds more readily than calcium. It is found in both plant and animal substances as is calcium. In some plants and in some parts of the plant, as in the seeds of grains, it is found more abundantly than calcium. It is generally considered one of the essential elements of plant food. The compounds of magnesium resemble those of calcium in many respects, but differ materially from the calcium salts in both chemical and physical properties.

177. Magnesium Salts.—Magnesium carbonate and magnesium sulfate (Epsom's salt) are among the most common of the magnesium compounds. Magnesium chlorid, $MgCl_2$, and $MgSO_4$ are found as double salts in the Stassfurt deposits. Magnesium oxid is obtained by the combustion of magnesium. Magnesium also forms other compounds as nitrates, phosphates, silicates, etc.

Experiment 29.—Hold a piece of magnesium ribbon about an inch long in the forceps and apply a lighted match to the ribbon. Examine the product.

Questions. (1) What are some of the chemical properties of the element as observed from this experiment? (2) What product was formed? Write the reaction. (3) Which would weigh more, the original magnesium ribbon or the white powder obtained from its combustion? Why? (4) Why does magnesium produce such an intense light?

CHAPTER XX

Iron, Aluminum, and Their Compounds

178. Occurrence of Iron.—Iron is found in nature mainly in the form of its oxids, hematite, Fe_2O_3, and magnetite, Fe_3O_4. It also occurs in the form of carbonate, $FeCO_3$, pyrite, FeS_2, and brown iron ore or basic hydroxid. It is found in the soil in combination with silicon and other elements, forming double silicates. It enters into the composition of all plant and animal bodies and takes an essential part in plant growth and animal life. Some waters contain carbonate of iron which, like calcium carbonate, is soluble in the presence of carbon dioxid; upon exposure to the air, the iron is precipitated as hydroxid, forming a brown deposit. Iron takes an important part in industrial operations and its chemistry has been more extensively studied than that of any other element.

179. Reduction of Iron Ores.—Only iron ores of a high degree of purity are ready, as mined, for the blast-furnace. Magnetic iron ore is concentrated and separated from its impurities by magnetic concentrators. The blast-furnace used for the production of cast iron is constructed of brick and is shown in Fig. 59. Ore, coke, and flux, usually limestone, are mixed in the right proportion and introduced into the top of the furnace. The flux is used to separate the impurities, forming a fusible slag which is largely calcium silicate. Hot air is forced into the furnace by means of blowing engines, through tuyeres.

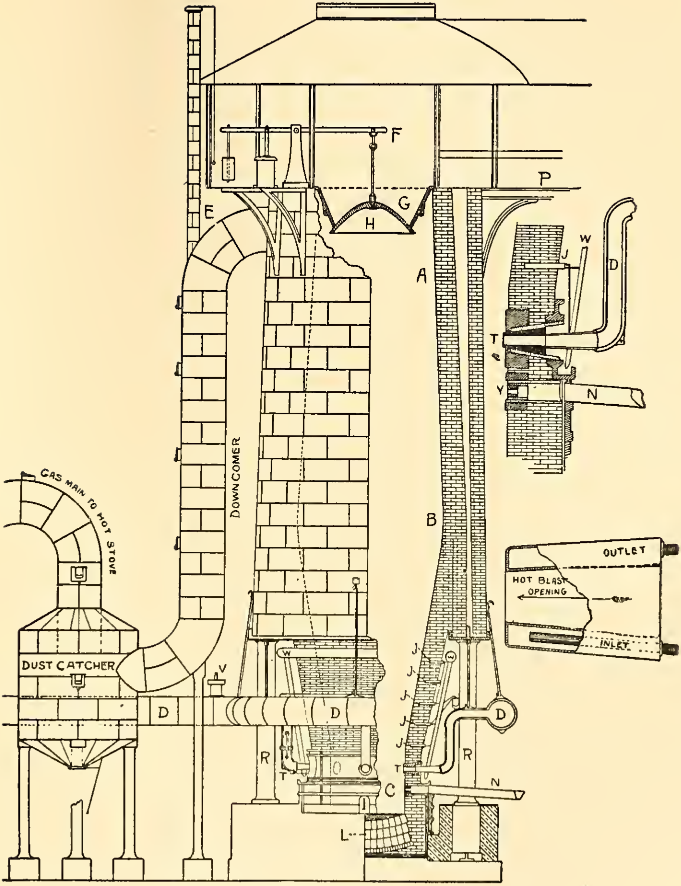

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Fig. 59. Blast-furnace (after Hart).

The carbon dioxid produced first is reduced to carbon monoxid which passes over the heated ore in the upper part of the furnace, and is the main reducing agent of the blast-furnace. The carbon monoxid given off at the top of the furnace is collected and used for heating the blast. The furnace is constructed so as to utilize the heat to the best advantage and so that the blast can act efficiently. The slag which carries a large portion of the impurities of the ore, being lighter than the molten iron, collects on the surface and is removed from time to time. The molten iron is run off from the bottom of the furnace into molds; iron that is produced in this way is known as pig iron. It contains a number of impurities as phosphorus, carbon, silicon and sulfur.

180. **Wrought Iron.**—Wrought iron is produced from cast iron by two processes: (1) the puddling process which consists of oxidizing the impurities by means of a blast of hot air which is passed over or blown throuhg the iron, this is known as the Bessemer process; and (2) the cementation process by which the cast iron is mixed with iron ores reasonably pure and heated to a high temperature so that the oxygen of the ores may oxidize the carbon, phosphorus and sulfur of the cast iron. Wrought iron is the purest commercial form of iron. It usually contains about 0.5 per cent. of carbon, and melts at about 2000° C. The nature of the impurities determines the character of both wrought iron and steel, as any increase in the amount of carbon decreases its malleability and other desirable properties.

181. **Steel.**—This form of iron contains less carbon

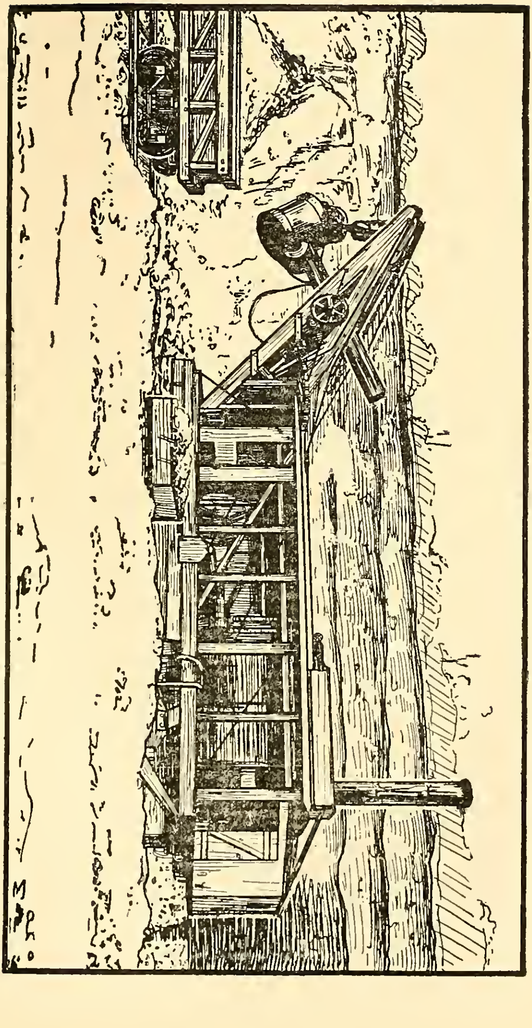


Fig. 60.—Surface-mining of iron ore with steam shovel, Iron Mountain, Minn.

than cast iron, but more than wrought iron. It is prepared by oxidizing the impurities of iron by means of a blast of hot air. This is accomplished by heating the cast iron in converters and then forcing through it a blast of hot air which oxidizes the larger portion of the impurities. By adding cast iron, steel containing almost any desired amount of carbon can be obtained. Iron and steel wire are made by drawing rods through hardened steel plates, the material being properly tempered during the operation. The thin coat of oxid formed on the surface is removed by dipping the wire into a bath of dilute sulfuric acid.

182. **Rusting of Iron.**—Iron in all of its forms readily undergoes oxidation and rusting, due to the joint action of oxygen and water which results in the production of a basic oxid of iron. When the surface of iron is protected, as by painting, oxidation and rusting are prevented. When iron is heated to its kindling temperature, it readily oxidizes as in Experiment 1. In the welding of iron, oxidation is prevented as far as possible by manipulation and occasionally by the use of materials, as borax, to remove the thin coating of oxid. Iron is readily acted upon by all acids, forming a large number of salts.

183. **Iron Compounds.**—Iron forms two series of salts: ferrous and ferric. Ferrous sulfate, $FeSO_4$, commonly called copperas, is used most extensively of any of the iron salts especially for the dyeing of cloth, and to some extent as a disinfectant.

Experiment 30.—Dissolve 0.5 gram of ferrous sulfate in 20 cc. of water. Filter if the solution is not clear, and divide the filtrate into two portions. To the first portion, add a few drops of ammonium hydroxid until a precipitate is obtained. To the second portion, add about 5 drops of strong nitric acid. Heat to boiling; when cool, add ammonia to neutralize the acid and precipitate the iron. The nitric acid oxidizes the iron and changes it from the ferrous to the ferric condition. Compare the two precipitates.

Questions. (1) What was formed when NH_4OH was added to $FeSO_4$? Write the reaction. (2) Give the color and other physical properties. (3) What change did the HNO_3 produce? (4) What change did you observe in the color of the solution during the boiling? (5) What was produced when NH_4OH was added to $Fe(OH)_3$? Write the reaction. (6) Give the color and some of the physical properties. (7) How does this last precipitate differ from the first one obtained?

Experiment 31.—Dissolve 1 gram tannic acid in 25 cc. of hot water. Dip a piece of cotton cloth into this solution. Dry the cloth and then dip it into a solution of ferrous sulfate (1 gram per 25 cc. of water). After the cloth has dried, see if the color can be removed by washing. Add 5 cc. of ferrous sulfate solution to 5 cc. of tannic acid solution. Observe the result. The $FeSO_4$ forms, with the tannic acid, iron tannate.

Questions. (1) Would the $FeSO_4$ alone give the same color to the cloth? Why? (2) Was the color produced a permanent one? (3) Tea contains tannic acid; why does tea prepared in an iron kettle give a black infusion? (4) What was produced when the solution of $FeSO_4$ was added to the tannic acid?

184. Occurrence of Aluminum.—Aluminum is a grayish white metal much lighter than iron and of greater tensile strength and is found mainly as one of the constituents of clay that is formed from the disintegration of feldspar, a double silicate of potassium and aluminum. It is also found in other combinations, as in mica and cryolite, and is present in nearly all soils and in small amounts is found in plant substances although it takes no part as plant food. Aluminum is not easily isolated from its compounds. It can be produced by treatment of its chlorid with sodium but is now quite extensively prepared by electrolysis. When pure, it is not as readily oxidized or acted upon by acids as is iron. Aluminum forms a large number of compounds and also alloys with many of the metals.

185. Alums.—In industrial operations, alum is used the most extensively of any of the compounds of aluminum. An alum is a double sulfate of aluminum. It has the general composition of $MAl(SO_4)_2 12H_2O$ in which M represents any bivalent metal as potassium. The Al can also be replaced by a trivalent element. Alum is extensively used in the tanning of leather, manufacture of paper, and in the coloring of cloth as the basis of the mordant or material for making the dye permanent. Alum is also used occasionally in the preparation of baking-powders.

Experiment 32.—Add a few drops of alum solution to a test-tube containing 5 cc. of water, and then add a few drops of tincture of logwood and 2 cc. $(NH_4)_2CO_3$. Observe the result. Mix about 2 grams of flour in a dish with water containing a few drops of alum. Add a few drops of logwood and the same amount of ammonium carbonate solution ; mix well, and observe the result. Repeat the test, using a baking-powder, and test for the presence or absence of alum. In the presence of alum, a blue color is always obtained with tincture of logwood and ammonium carbonate solution.

Experiment 33.—To a solution of egg albumin, add a few drops of alum solution and observe the result.

Questions. (1) Does the alum cause a precipitate? (2) Of what is the precipitate composed? (3) How would alum act in the digestive tract in the presence of soluble albuminous compounds? (4) Why is alum an undesirable ingredient in baking-powders and foods.

186. Pottery.—Pure clay or kaolin is used for the manufacture of the best grades of porcelain and pottery. The plastic clay is modeled into the desired form and then dipped into a bath containing feldspar and other materials which, when fused, form the glaze. Ordinary earthenware is made from impure clay which contains compounds of iron and other elements. Brick and tile are also made from clay, the physical properties, as color, hardness, weathering properties, etc., depending upon the amounts of iron, lime, magnesia, and alkalies present· As ordinarily found in the soil, clay is mechanically associated with a large number of other substances, many of which contain the elements essential to plant life as potassium and calcium. Pure clay itself contains no plant food, but clay soils are usually among the most fertile because, along with the disintegration of feldspar and other rocks, various minerals that impart fertility are made available and are associated with the clay.

CHAPTER XXI

Copper, Zinc, Lead, Tin, Arsenic, Mercury, and Their Compounds and Alloys.

187. Commercial Importance.—The compounds of copper, zinc, lead, tin, and arsenic, while they do not enter into the composition of either plant or animal bodies, are of value in agriculture because of their presence in many useful materials.

188. Occurrence of Copper and Its Metallurgy.—This element is found in the free state and also in combination with oxygen as CuO and Cu_2O, with sulfur as Cu_2S, and with iron and sulfur as copper pyrite, $Cu_2S.Fe_2S_3$. The ores of copper are first roasted, and if iron is present in large amounts, it is removed as a silicate. The "matte," as it is called, thus produced is subjected to further refining. Copper is also produced by electrolysis.

189. Copper Sulfate.—This salt is used the most extensively of any of the copper compounds and is produced by the action of sulfuric acid upon either metallic copper or its sulfid. It crystallizes with 5 molecules of water of crystallization. It is commonly called blue vitriol, and is extensively used in the preparation of pigments, for the preservation of wood, for copper-plating and for the treatment of fungus diseases in plants as in the Bordeaux mixture where it is the principal ingredient.

Experiment 34.—Dissolve 6.2 grams of copper sulfate and 3.50 grams of sodium potassium tartrate in 100 cc. of water. Dissolve a small amount of glucose (0.1 gram) in 5 cc. of water, add 5 cc.

of alkaline copper sulfate solution and heat to boiling. Observe the brown precipitate of Cu_2O. The amount of Cu_2O produced is proportional to the amount of glucose present and when the work is carefully done and the copper weighed or determined by other means, the percentage amount of glucose in a material can be determined. A hot alkaline solution of copper sulfate is reduced to Cu_2O in the presence of glucose, and a few other organic compounds.

190. Bordeaux Mixture.—In this preparation, the copper is present as an insoluble hydroxid. To prepare the Bordeaux mixture 12.5 pounds of copper sulfate are dissolved in about 2 gallons of hot water; 3.5 pounds of lime are slaked in about 2 gallons of water, and strained into a barrel through a coarse cloth to remove any large pieces. The solution of copper sulfate is then poured into the barrel and well stirred. The reaction which takes place is

$$Ca(OH)_2 + CuSO_4 = Cu(OH)_2 + CaSO_4.$$

In the preparation of Bordeaux mixture, it is the aim to use just a sufficient amount of lime to combine with all of the copper.

191. Occurrence of Zinc.—This metal is found in nature mainly as zinc carbonate, $ZnCO_3$, and to a less extent as the sulfid. Small amounts are found in other forms. Zinc is separated from its ores by roasting with charcoal which, volatilizes and it is then collected as zinc dust. It is then purified and prepared for various purposes.

192. Compounds of Zinc.—Zinc forms a large number of compounds as $ZnCl_2$, $Zn(OH)_2$, ZnS, and $ZnSO_4$.

Some of the zinc salts are used in the preparation of paints, while the metal itself is used in many ways as in the preparation of alloys, solder, and galvanized iron.

193. Galvanized Iron.—Iron is galvanized by being covered with a layer of zinc. Galvanized iron is extensively used for water pipes because it does not rust so readily as ordinary iron. When heated, however, the zinc coating of the galvanized iron is removed.

194. Occurrence of Tin.—Tin is found in nature largely in the form of the oxid, SnO_2, and, to a less extent, in combination with other metals. The oxid is heated in a furnace with charcoal, and the molten tin cast into bars.

195. Tin Salts.—Tin forms two series of salts, stannous and stannic. In the former, the element is bivalent, and in the latter, it is tetravalent. Stannous and stannic chlorid, the sulfid, oxid and hydroxid are among the more common tin salts. They are used in the arts in various ways as pigments and as mordants in the coloring of cloth. Tin forms a number of alloys and is extensively used for roofing and other purposes. Ordinary tinware is simply iron-coated with a layer of tin.

196. Occurrence of Lead.—Lead is found principally in the form of sulfid (galena). It is also found in combination with silver and other metals, and, in the process of refining of silver, is separated as a by-product.

197. Oxids of Lead.—There are four oxids of lead, namely : lead monoxid, PbO, lead peroxid, PbO_2, lead suboxid, Pb_2O, and lead sesquioxid, Pb_2O_3. The suboxid, Pb_2O, is produced when lead is exposed to the air; in a pure condition, it is a black powder. Lead oxid, PbO, is a yellow powder which, if heated, produces litharge, a yellowish red material. This substance is obtained largely in the separation of lead from silver. Lead peroxid, PbO_2, is an oxidizing agent, and in some respects resembles manganese dioxid. Red led or minium, Pb_3O_4, is produced by heating lead oxid, and is used as a pigment.

198. Lead Carbonates.—The normal carbonate, $PbCO_3$, is occasionally found in nature. The basic carbonate, $Pb(OH)_3 \cdot 3PbCO_3$, is common white lead, which is extensively used as a pigment. It is produced by different methods from litharge and other compounds of lead, as well as by treatment of the metal itself.

199. Lead Salts.—Lead nitrate, $Pb(NO_3)_2$, is produced by the action of nitric acid on lead; and lead sulfate, by the action of a sulfate upon a soluble lead salt. Lead chlorid, $PbCl_2$, is precipitated whenever a chlorid or hydrochloric acid is added to a solution containing a lead salt. The salts of lead are more insoluble than those of many other metals.

200. Uses of Lead.—Lead is used for making water pipes, for lining tanks, particularly those in which sulfuric acid is stored, in the preparation of solder, and in many alloys. Lead is insoluble in most waters although the salts and organic matter in some waters may cause a sufficient amount to dissolve to render the use of lead pipes objectionable from a sanitary point of view.

201. Occurrence of Arsenic.—This element occurs in the free state to a limited extent, but usually in combination with other elements, as oxygen, iron, and sulfur. In some of its properties, arsenic resembles phosphorus, and forms similar compounds, although arsenic has weaker acid properties than phosphorus. It forms a large number of compounds, among which are the arsenates, and arsenites which are salts of arsenic and arsenious acids. In the presence of a strong base element, arsenic deports itself as an acid while, in the presence of a strong acid element, it exhibits basic properties. Other elements, particularly antimony and bismuth, and to a less extent aluminum, have this same property of acting both as an acid- and base-forming element. Some of the compounds of arsenic are extensively used as pigments and insecticides.

202. Paris Green.—Pure Paris green is an aceto-arsenite of copper and has the following composition : Copper oxid, 31.29 per cent., arsenious oxid, 58.65 per cent., acetic acid, 10.06 per cent. Some of the commercial grades of Paris green contain soluble forms of arsenic, while others are adulterated with lime and insoluble silicates. The arsenic should be insoluble and have no injurious effect upon vegetation. In case soluble arsenic is present, the foliage is destroyed. Pure Paris green should completely dissolve in hydrochloric acid. In case silica is present, an insoluble residue appears when the material is treated with hydrochloric acid. London purple and various arsenates and arsenites are occasionally used for insecticides. London purple contains soluble arsenic. In case of accidental poisoning with Paris green, hydroxid of iron is usually employed as an antidote.

203. Occurrence of Mercury.—Mercury is found in nature mainly in the form of the sulfid, HgS, commonly called vermilion which, when roasted, yields SO_2 and Hg. Mercury is extensively used in the preparation of alloys and amalgams.

204. Compounds of Mercury.—Like copper, tin and many other elements, mercury forms two series of salts, the mercurous and mercuric compounds. Mercurous and mercuric oxids, Hg_2O and HgO, mercurous and mercuric chlorids, HgCl and $HgCl_2$, and the nitrates and sulfids are among the more important compounds of mercury. Mercuric chlorid is employed as an insecticide and also as a germicide. It is very poisonous and is very destructive to all forms of animal and plant life; it is frequently used for the treatment of fungus diseases of plants.

Experiment 35.—Replacement of metals. Place, in separate test-tubes, (1) 5 cc. of silver nitrate, (2) a piece of copper, and (3) 5 cc. of lead nitrate. To the first test-tube, add a piece of copper foil, to the second a small piece of lead, and to the third, a piece of zinc. After a few minutes, examine the contents of the various test-tubes and observe the results. Copper has the power of replacing silver in solution, lead has the power of replacing copper, and zinc has the power of replacing lead.

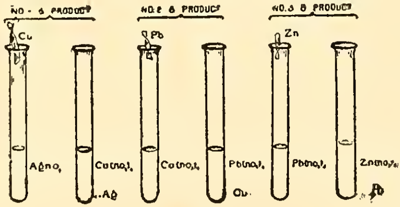


Fig. 61.

The more electro-positive elements replace those which are less electro-positive. Observe in these experiments that the copper is coated with silver, the lead with copper, and the zinc with lead. Write the following reactions which have taken place:

(1) $AgNO_3 + Cu =$
(2) $Cu(NO_3)_2 + Pb =$
(3) $Pb(NO_3)_2 + Zn =$

Questions. (1) Which element is the most positive? (2) What elements can zinc replace? (3) Why does copper replace silver? (4) Why does lead replace copper? (5) What does this experiment show as to the relative properties of the three elements, copper, silver and lead?

CHAPTER XXII

Water Content and Ash of Plants

205. Water.—Water is present in all food materials, and in many cases makes up a very large portion of the weight of a substance. In vegetables, in milk, and in the juices of meat, water is present to such an extent as to be perceptible to the senses. Substances like flour, meal and starch, which appear perfectly dry, are not free from water, but contain from 9 to 12 per cent. This hydroscopic water, as it is called, is held mechanically by the particles of which the material is composed, and the

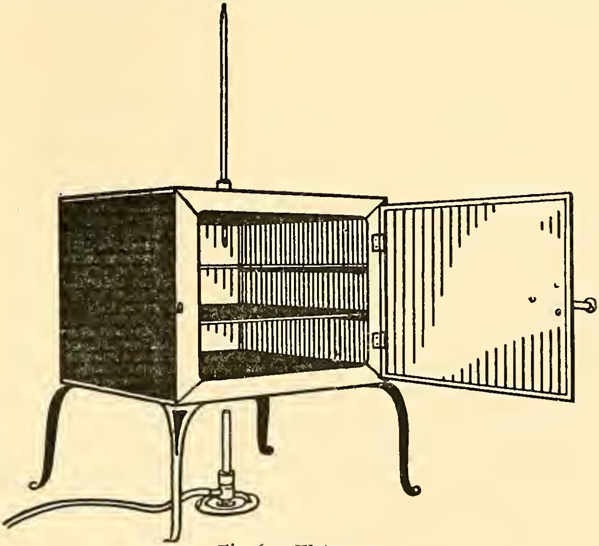


Fig. 62.—Water-oven.

amount thus held depends upon the extent of the previous drying of the material and the hydroscopic condition of the air. Inasmuch as air always contains some water, it necessarily follows that all substances exposed to the air must likewise contain some water.

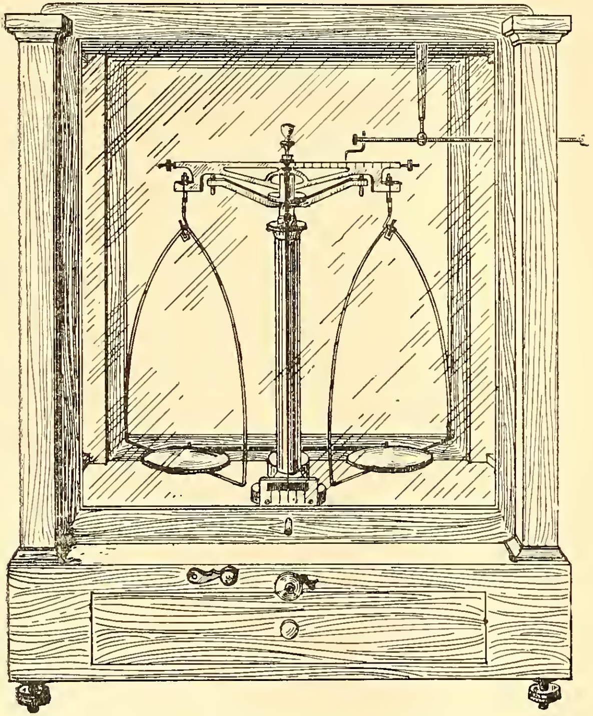


Fig. 63. Analytical balance.

In order to remove the last traces of water from a substance, it is dried in either a water- or a hot-air oven at a temperature of 100° C.,—the boiling-point of water. This converts all of the water in the material into steam, which is then expelled. A water-oven, shown in Fig. 62, has double walls, the space between the walls being partially filled with water, which is kept boiling by means of a gas burner placed below the oven. The substance is weighed in a suitable dish and then dried in the water-oven until the weight is reasonably constant, the loss of weight being considered water.

The determination of water in foods, although apparently simple, is a difficult and troublesome chemical process because many foods, when heated to 100° C., suffer changes, and give off volatile organic compounds along with the water; or the organic matter may undergo a change in composition, as oxidation. For determining the absolute moisture content of foods, the chemist employs a drying bath of different pattern from that shown, and the material is dried in a current of some neutral gas, as hydrogen, to prevent oxidation of the substance. All of the dishes in which the substances are placed, during analysis, are dried and cooled in desiccators out of contact with air, so as to remove all traces of hydroscopic moisture. The weighings are made on analytical balances which are scales of extreme accuracy (see Fig. 63). The determination of water is one of the most difficult parts of the analysis of plant or animal substances.

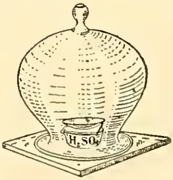


Fig. 64. Desiccator.

206. Dry Matter.—The dry matter of a material is the portion which is left after all the water has been removed. Dry matter, as the term implies, is the dry material free from all traces of hydroscopic moisture, and the amount is determined by subtracting the per cent. of water from 100. For example, if flour contains 12 per cent. water there will be 88 per cent. of dry matter. The amount of dry matter in substances ranges between wide limits as 7 per cent. and less in some fruits to 99 per cent. in sugar.

Experiment 36.—Determination of water in potato. Carefully weigh an aluminum dish (Fig. 65). Cut thin slices from different parts of a potato and reduce them to 1/8-inch cubes. Weigh in the dish, some of these pieces, forming a layer not more than two deep. Record the weight, place in the dish a small piece of paper with your initials, then set the dish in the water-oven (Fig. 62), and allow it to remain twenty-four hours, or until the next exercise. After drying, weigh again, and from the loss of weight calculate the per cent. of water in the potato. (Weight of potato and dish before drying, minus weight of potato and dish after drying, equals weight of water lost. Weight of water divided by weight of potato taken, multiplied by 100, equals the per cent. of water in the potato.)

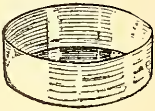


Fig. 65.

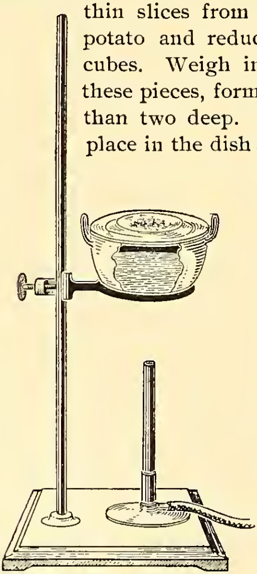


Fig. 66.

Experiment 37.—Water in flour. In the same manner, determine the per cent. of water in flour, using about 2 grams of flour, and noting the exact weight before and after drying.

Experiment 38.—Water in milk. Weigh a watch-glass and place it on the water-bath (see Fig. 66). Measure with a pipette 3 cc. of milk into the watch-glass. Evaporate to dryness on the water-bath, completing the process in the water-oven. When dry, weigh, and from the loss of weight, calculate the per cent. of solids. Sp. gr. of milk, 1.032. 1 cc. $H_2O = 1$ gram. 1 cc. milk $= 1.032$ grams. If skim milk is used, the sp. gr. is 1.035.

Experiment 39.—Water in clover. Weigh an aluminum dish. Take three or four large clover plants and cut fine with shears or knife. Weigh a portion in the dish; dry, and weigh again as in Experiment 36. Determine the per cent. of water in clover.

Questions. (1) How did the potato, after drying, compare in appearance and volume with the material before drying? (2) How does the percentage amount of water which you have obtained, compare with the figures given in the tables of analysis. (3) In the determination of water in milk, what was the appearance of the milk solids? (4) What classes of compounds are present in milk solids. (5) How does the amount of water obtained in Experiment 37 compare with the amount given in the tables of analysis? (6) What would be the shrinkage in weight of a barrel of flour if 2 per cent. of moisture were removed, and what would be the increase in weight if 2 per cent. of moisture were absorbed from the air? (7) How does the amount of water obtained in Experiment 39 compare with that obtained from the other materials? (8) How much water is present in a ton of green clover?

207. Plant Ash.—The ash of a plant, or of any material, is that portion which remains after the substance is burned at the lowest temperature necessary for complete combustion. It is sometimes spoken of as the mineral or inorganic part, also as the non-volatile part, and includes all of the materials, with the exception of water and nitrogen, which the plant takes from the soil during growth. The term ash as used in chemistry differs from the term as ordinarily used in that the chemical ash is pure ash, free from unburned particles of carbon, and also contains elements, as sodium, chlorin, sulfur and phosphorus, traces of which are volatile at a high temperature. Crude ash is obtained by burning a substance until all of the carbon is oxidized.

Experiment 40.—Determination of ash. Weigh to the second decimal place in grams, a dish given out for this experiment. Then weigh into the dish about 2 grams of dry clover or other hay, place in the muffle furnace, and let it remain until there is no charred material left. Cool on an asbestos mat. Weigh again and determine the per cent. of ash from the material taken and the weight of the ash obtained. Calculate the per cent. of organic matter. Save the ash for future experiments. [The 500, 200, and 100 mg. weights are to be recorded as 0.5, 0.2, and 0.1 gram; the 50, 20, and 10 mg. weights as 0.05, 0.02, and 0.01 gram. If one used a 10-gram weight, a 500-mg. weight, and a 20-mg. weight, it would be written 10.52 grams.]

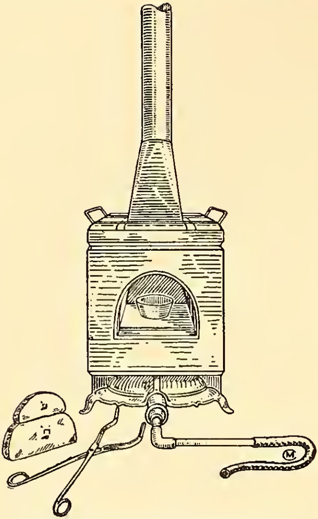


Fig. 67.—Muffle furnace used for determination of ash.

208. Form of the Ash Elements.—None of the elements present in the ash of plants ever exist there

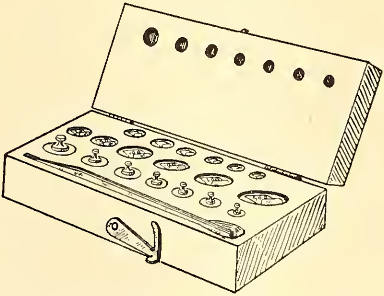


Fig. 68.—Weights for balance.

in the elementary or free state, as free sodium or free silicon, but they are always in chemical combination, forming salts, or are combined with the elements which constitute the organic part of the plant. The ash elements are never present in the form of free acids or free bases, although, in chemical analyses, they are expressed as acid or basic oxides. Phosphorus, for example, never exists in the plant as free phosphorus or as phosphoric acid, but either as a phosphate or combined with some of the elements which constitute the organic part.

209. Amount of Ash in Plants.—While the amount of ash in plants is fairly constant, it will be found to vary with the stage of growth, climatic conditions, and nature of the soil. In mature agricultural plants, the amount rarely exceeds 10 per cent. of the dry weight of the material. Clover grown in different localities is found to contain from 6 to 8.5 per cent. ash; other crops also show limited variations. The ash is not evenly distributed throughout all parts of a plant; the leaves, for example, contain a larger amount than the seed. In the case of corn, the amount of ash in different parts is as follows:

	Per cent.
Mature plant	5.8
Roots	3.5
Leaves	8.1
Stems entire	6.6
Grain	1.4

As previously stated, the ash elements of a plant, together with the nitrogen and water, represent all of the material which is taken from the soil. In 100 parts of the dry material of any crop, from 5 to 10 parts are derived from the soil while 90 to 95 parts are supplied either directly or indirectly from atmospheric sources.

210. Importance of Ash Elements.—Plant ash is composed of potassium, sodium, calcium, magnesium, iron, phosphorus, sulfur, silicon, and chlorin compounds. These elements, with a few others present in small amounts, as aluminum and occasionally manganese, boron, etc., are the elements which make up the mineral matter of plants. Some of the ash elements, as potassium and phosphorus, are absolutely necessary for the life of the plant, while others, as aluminum and silicon, are, so far as known, unnecessary. The essential ash elements are potassium, calcium, magnesium, iron, phosphorus and sulfur. The non-essential elements are sodium, silicon, chlorin, and aluminum. But in some alkali and sea plants, sodium, chlorin, and other elements are essential for growth.

Chemically considered, the elements found in the ash of plants are divided into two classes :

(1) Metals or base-forming elements.		(2) Non-metals or acid-forming elements.	
Potassium	K	Phosphorus	P
Sodium	Na	Sulfur	S
Calcium	Ca	Silicon	Si
Magnesium	Mg	Chlorin	Cl
Iron	Fe		
Aluminum	Al		

To the above list must be added small amounts of other elements occasionally found in the ash of plants, and also oxygen, which is in chemical combination with all of the above elements.

The essential ash elements are absolutely necessary for the normal growth and development of plants. They take a direct part in the production of plant tissue. The part which each ash element takes in plant growth has been known only for a comparatively short time. At one time, it was believed that the ash elements were largely accidental that the plants in taking up water from the soil could not well keep out the soluble earthy matters, but the methods of sand and water culture have demonstrated the necessity and the functions of the various ash elements.

211. Water Culture.—In water-culture experiments, the seed is germinated and then the roots are suspended in water containing small amounts of the different ash elements. The roots are protected from the light, and the solution is frequently changed. In case it is desired to learn what effect the absence of an element has upon the growth and development of the plant, all of the elements are supplied in known amounts except the one in question which is withheld altogether. The development of the plant is observed, and if it reaches maturity and produces fertile seeds, it is concluded that the element withheld is not necessary to plant growth, while on the other hand, if the plant does not develop naturally, the element withheld is considered a nec-

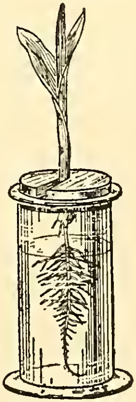


Fig. 69.—Water culture.

essary one. By eliminating the ash elements in order, a conclusion may be drawn as to the part which each separate element takes in plant nutrition. After repeated experiments with various modifications, aided by chemical and microscopic examinations of the plant, the functions of an element are determined. When a plant develops under normal conditions, there is a definite part which every essential element performs during growth. In fact, a plant may be fed, and the effects of the food be observed as accurately as in the case of the feeding of men or animals.

212. Sand Culture is essentially the same in principle as water culture. Pure sand (SiO_2) is treated with strong acids, washed with distilled water, and ignited. When properly prepared, this leaves a perfectly sterile medium to which is added, as desired, known amounts of the various ash elements.

Occurrence and Function of Ash Elements

213. Potassium.—Potassium is one of the most important and least variable of all the elements found in the ash of plants. It is quite evenly distributed throughout the growing plant and generally occurs in the entire plant in the largest proportion of any of the essential ash elements. It is taken up in the early stages of plant growth and is always present to the greatest extent in the active and growing parts, as in the leaves where the production of plant tissue occurs. Potassium is one of the elements most essential for the plant's development.

The function of potassium is apparently to aid in the production and transportation of the carbohydrate compounds, as starch and sugar, and thus indirectly in the formation of all organic matter. In sugar- and starch-producing crops, as sugar-beets and potatoes, it takes an important part in the growth and development. Potassium doubtless has much to do in the way of regulating the acidity of the sap by forming organic salts such as potassium bitartrate in grapes. At the time of seed formation there is a slight retrograde movement of the potash, in some cases a small part being returned to the soil. The supply of available potash in the soil has great influence upon the vigor of plant growth. Weak and sickly plants are always deficient in potash. Some crops require more for growth than do others and some experience difficulty in obtaining it. Some plants contain such large amounts of potash that they are called "potash plants."

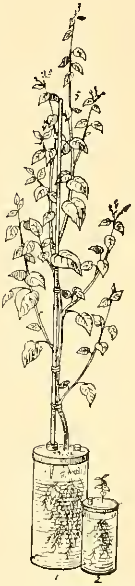


Fig. 70.—Plants grown with and without potash.

Experiment 41.—Alkalinity of ashes. Weigh 2 grams hard wood ashes into a beaker containing 100 cc. H_2O. Heat over a sand-bath until it boils; filter. To one-half of filtrate, add 10 drops of cochineal solution; from the burette (see Fig. 38), add dilute (1 cc. acid, 40 cc. H_2O) HCl until the solution is neutral. The alkali in wood ashes is mainly K_2CO_3 which is neutralized with HCl. Write the reaction. Test both leached and unleached ashes. Note number of cubic centimeters HCl used in each case. What do the results indicate?

214. Sodium.—This element, which resembles potassium in its chemical deportment, is not absolutely necessary for agricultural plants and does not occur in the ash in such large amounts as potassium. Nearly all agricultural plants are brought to maturity without its aid except for the small amount in the seed. The amount, if any, which plants require is very small, not sufficient to take into consideration. It is supposed to be present as an accidental ingredient, because sodium chlorid is universally present in the soil, in water, and occasionally traces of it are in the air; hence plants could not very well exclude it. Some alkali plants require and store up large amounts of sodium compounds. Unlike potassium, sodium is not so evenly distributed through the plant. It has no special movement, but is found mostly in the lower parts of the plant. Seeds contain but little of it, more being present in the straw and stems.

215. Calcium.—This element is always present in the ash of plants. None of the higher plants can reach maturity without a normal supply. Some, like clover, beans, peas, and lucern, require so much for their development that they are called "lime plants." Accumulations of lime are found in many leafy plants, particularly clover, where crystals of calcium oxalate may be observed. In leaves, it appears to have the special function of aiding in the construction of the cell walls. No new plant cells can be produced without the aid of calcium.

From the culture experiments of various investigators, the element calcium appears to take a prominent part in the production of new tissues. Whenever it is withheld, the growth of the plant is restricted. Some plants, after their growth has been checked by withholding calcium, will show increased vigor within a few hours after it is supplied. Calcium is assimilated in the early stages of plant development. In wheat, for example, 80 per cent. is assimilated before the plant heads out. Calcium assists in imparting hardiness to crops. It does not accumulate in the seeds to such a great extent as do other elements. Only about a tenth of the total amount removed in grain crops is in the seeds, the remaining nine-tenths being present in the straw. Crops grown on lime soils are usually well nourished, and are more capable of withstanding unfavorable climatic conditions as drought and early frosts than are crops not so liberally supplied with lime.

Experiment 42.—Lime, CaO, in plant ash. Transfer the ash from Experiment 40 to a beaker containing 5 cc. HCl and 50 cc. H_2O; heat ten minutes, filter, and divide into two portions. Save portion for Experiment 44. Make one portion neutral with ammonia, NH_4OH. Add 5 cc. NH_4Cl solution. To the solution, add 5 cc. ammonium oxalate, $(NH_4)_2C_2O_4$; note the precipitate which is calcium oxalate, CaC_2O_4.

Into a separate test-tube put 0.1 gram $CaCl_2$, add 5 cc. H_2O and a little HCl until acid; then nearly neutralize with NH_4OH and add NH_4Cl and $(NH_4)_2C_2O_4$. Compare this precipitate with that from the clover ash. Observe, in this second test, that you have taken a pure calcium salt, and that the same precipitate was given as by the plant ash. Write the following reactions which have taken place: $CaC_2O_4 + \text{Heat} = ?$ $CaCO_3 + HCl = ?$ $CaCl_2 + (NH_4)_2C_2O_4 = ?$

216. Magnesium is also an essential element. It occurs in all plants and farm crops in somewhat smaller amounts than calcium but in the seeds of grains it is stored up three times more liberally. Magnesium is assimilated more slowly than calcium; in fact it is assimilated, as a rule, more slowly than any other ash element. The plant does not require magnesium until the approach of seed formation, although a small amount is necessary for perfect leaf action as it enters into the chemical composition of the chlorophyl. When plants are grown with an incomplete supply of magnesium, the seeds are frequently sterile. In culture experiments, the absence of magnesium is not observed so much in the first stages of growth as when the time of seed formation approaches when its absence is followed by restricted development.

217. Aluminum is found in the ash of many plants, as wheat, peas, beans, and rice, although it occurs in very small amounts and, so far as known, is not essential for plant growth. Most soils contain traces of soluble silicates of aluminum, and hence plants cannot well be free from it.

218. Iron in small amounts is necessary for plant growth. It occurs in about the smallest amount of any of the ash elements, but is always present in plants. When plants are unable to obtain their requisite supply of iron, the production of chlorophyl does not take place and they fail to develop a normal green color.

The function of the iron is to assist in the formation of chlorophyl, the coloring-matter of plants. It is not known whether iron enters into the chemical composition of the chlorophyl, or is simply organically associated with it

219. **Phosphorus,** in the form of phosphates, is found in all parts of plants. It is one of the essential elements for plant growth. Its function is to aid in the production and transportation of the proteid bodies. The phosphorus and nitrogen compounds are closely associated in the work of producing proteids which can take place only in the plant cells. The proteid compounds produced in the leaves of plants are finally transported to the seed. Many proteids which are insoluble in water are soluble in the presence of phosphate compounds. The phosphates are essential in the early stages of the plant's development. In the case of wheat, 80 per cent. is assimilated in the first fifty days, and in other crops, the assimilation is equally rapid. The phosphates accumulate to a greater extent in the seeds of grains than in the leaves and stems. From 60 to 75 per cent. of the total phosphates is removed in the seeds. The loss of phosphates from the farm is one of the reasons why soils decline in fertility.

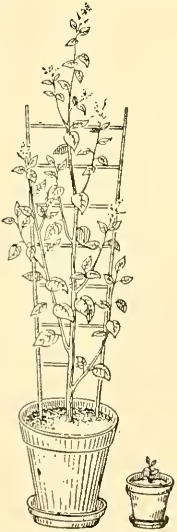


Fig. 71.—Plants grown with and without phosphoric acid.

Experiment 43.—Phosphoric acid in seeds. Crush 25 kernels of wheat in a mortar. Place the crushed wheat in a small Hessian crucible and ignite; when cool, transfer the charred mass to a small beaker. Add 10 cc. HNO_3 and 50 cc. H_2O, and boil ten minutes. Break up the charred particles with a stirring rod during the boiling. If the beaker shows signs of becoming dry, add a little hot water. Filter. To half the filtrate, add 3 cc. ammonium molybdate. The yellow precipitate is ammonium phosphomolybdate. See Experiments 17 and 18.

220. **Sulfur** also is an essential element of plant and animal bodies, but occurs in plant tissue in comparatively small amounts. It enters into the composition of albumin and other proteids. Sulfur is used by plants only in the form of sulfates. The part which it takes in plant life is to supply the sulfur for the proteid compounds which always contain this element in chemical combination. Culture experiments have shown that in its absence no growth results.

Experiment 44.—Sulfur as sulfates in plant ash. To the second portion of the filtrate from Experiment 40 add 2 cc. barium chlorid ($BaCl_2$), observe the result, and write the reaction, assuming SO_3 to be in the form of K_2SO_4. In a second test-tube, add a few crystals of Na_2SO_4 or K_2SO_4 to 10 cc. H_2O containing a few drops HCl. When dissolved add $BaCl_2$ and compare with precipitate obtained in first part of experiment (see Experiment 21).

221. **Chlorin** is not an essential ash element. It accumulates mainly in the lower part of the plant, and its presence appears to be accidental, it having no decided functions to perform. The statements made about sodium, its occurrence, distribution, and importance apply also to chlorin with which it is combined forming sodium chlorid.

222. **Silicon** occurs in all plants. It is found in largest amounts in the dense and older parts, as in the stalk and straw, where there is less activity. In some of the lower plants, as diatoms, there is so much silica that when the organic matter is removed by burning, a skeleton of silica

is left. It was formerly supposed that silica gave the stems of grains and grasses their stiffness. Perfect wheat, however, with normal strength of straw has been grown in the absence of silica, except for the small amount originally present in the seed. Lawes and Gilbert have shown that the lack of silica is not the cause of grain lodging. Some authorities claim that silica takes a part in plant economy and is necessary in seed formation. Whatever its function, it is not an important element as plant food, and there is always an abundance in the soil for crop purposes.

In the living plant, the mineral elements are not present in the same form or combination as in the plant ash. During growth, many of the ash elements are combined with the organic compounds, for example phosphorus, which forms phosphorized proteids and fats. The ash forms a part of the plant tissue. When the plant is burned, the organic compounds are volatilized, while the ash elements, which are non-volatile, are left. The essential ash elements are absolutely necessary, as food, for the growth and development of all crops, and plant growth is frequently arrested because of the lack of a sufficient supply for purposes of nutrition. The food requirements of individual farm crops are discussed in the "Chemistry of Soils and Fertilizers."

SUMMARY TABLE.

Plant ash elements.

Metals.	Formula of oxid.	Essential +. Non-essential —.	Occurrence.	Function.
Potassium	K_2O	+	Mainly in the active growing parts of plant leaves and stems.	Assists in formation of starch, carbohydrates and in plant growth in general, and makes plants vigorous.
Sodium	Na_2O	—	Stems and roots.	No function.
Calcium	CaO	+	Leaves and stems.	Assists in formation of plant cells, and makes plants hardy.
Magnesium	MgO	+	Seeds and leaves.	Aids in seed formation.
Iron	Fe_2O_3	+	Leaves and stems.	Aids in chlorophyl formation.
Aluminum	Al_2O_3	—	Lower parts of plants.	No function.
Manganese	Mn_2O_3	—	Lower parts of plants.	No function.
Non-metals.				
Phosphorus	P_2O_5	+	Seeds.	Leaf action and formation and movement of proteids.
Sulfur	SO_3	+		Production of proteids.
Silicon	SiO_2	—	Stems and leaves.	No apparent function
Chlorin	—	—	Lower parts.	No apparent function

Problem 1.—How many pounds of potash are removed from an acre of soil yielding 150 bushels of potatoes?

The potatoes weigh 60 pounds per bushel. $150 \times 60 = 9{,}000$ pounds, total yield of potatoes. The potatoes contain 24 per cent. dry matter (see Table). This dry matter contains 3.8 per cent. ash. Hence 2,160 pounds dry matter contain ($216 \times 0.038 = 81.9$) 81.9 pounds ash. 60 per cent. of this ash is potash; or (81.9×0.60) 49.1 pounds are potash. Therefore, 150 bushels of potatoes

COMPOSITION OF THE ASH OF FARM CROPS.

(NOTE.—Many of the analyses are from Wolff's "Aschen Analysen," while others were made by the author.)

			Composition of 100 parts of the pure ash.								
SEEDS.	D. M.	Pure ash.	K_2O.	Na_2O.	CaO.	MgO.	Fe_2O_3.	P_2O_5.	SO_3.	SiO_2.	Cl.
Wheat	approximately 90 per cent.	2.03	30.24	0.65	3.50	13.21	0.60	47.92	....	0.73	....
Oats		3.12	17.90	1.66	3.60	7.03	1.18	25.64	1.79	39.20	0.94
Barley		2.61	20.92	2.39	2.64	8.83	1.19	35.10	1.80	25.90	1.02
Rye		2.09	32.10	1.47	2.94	11.32	1.24	47.74	1.28	1.37	0.48
Corn		1.45	29.8	1.10	2.17	15.52	0.76	45.61	0.78	2.10	0.91
Flax		3.67	26.27	2.22	9.61	15.86	1.11	42.48	....	0.88	....
Clover		4.50	35.35	0.95	6.40	12.90	1.70	37.93	2.40	1.30	1.23
Peas		2.73	43.10	0.98	4.81	7.99	0.83	35.90	3.41	1.91	1.60
Beans		3.63	41.48	1.10	4.99	7.15	0.46	38.86	3.40	0.65	1.80
FODDERS.											
Clover	air dry, approximately 87 per cent.	7.02	27.25	0.80	29.26	8.32	0.57	10.66	....	6.18	....
Timothy		6.82	34.69	1.83	8.05	3.24	0.83	11.80	2.80	32.17	5.20
Brome grass		6.55	27.65	0.89	7.59	4.32	1.83	5.84	....	4.37	....
Corn		8.72	27.18	0.85	5.70	11.42	0.85	9.14	....	40.18	....
STRAWS.											
Flax		2.86	34.07	4.37	24.81	15.04	3.67	6.24	....	6.70	....
Buckwheat		6.15	46.60	2.20	18.40	3.60	....	11.19	....	5.50	....
Pea		4.80	21.40	5.70	38.80	7.20	1.40	7.10	....	5.40	....
Bean		6.10	32.70	8.70	25.30	7.30	1.70	7.90	....	5.50	....
Wheat		5.37	13.65	1.38	5.76	2.46	0.61	4.81	....	67.50	....
Oat		7.17	26.42	3.29	6.97	3.66	1.20	4 59	3.20	46.70	4.40
Barley		5.35	23.26	3.54	7.22	2.58	1.13	4.24	3.80	51.00	3.20
ROOTS.											
Potatoes	24	3.80	60.00	2.96	2.64	4.93	1.10	16.86	6.50	2.10	3.40
Sugar-beets	15	3.80	53.10	8.92	6.10	7.86	1.14	12.20	4.20	2.28	4.80
Turnips	12	8.00	45.40	9.84	10.60	3.69	0.81	12.71	....	1.80	5.00

remove from the soil 49.1 pounds of potash. In the same way, the amount of each separate element removed from the soil can be calculated.

Problem 2.—Calculate the pounds of total ash, K_2O, CaO, MgO, and P_2O_5 removed in 25 bushels of wheat.

Problem 3.—Calculate the same ingredients removed in 1,500 pounds of wheat straw. Compare these amounts with the corresponding elements removed in the grain (Problem 2).

Problem 4.—Calculate the CaO, MgO, K_2O, and P_2O_5 removed in 50 bushels of oats weighing 32 pounds per bushel.

Problem 5.—Calculate the same for 40 bushels of barley weighing 48 pounds per bushel. In what respects does the mineral food of barley differ from the mineral food of wheat?

Problem 6.—How much P_2O_5 is removed in 15 bushels of flax?

CHAPTER XXIII

The Non-Nitrogenous Organic Compounds of Plants

223. Organic Matter.—The organic matter of a plant or material of any kind is that portion which can be converted into volatile or gaseous products; it is the combustible part, and is simply a mechanical mixture of the various organic compounds, as starch, sugar, and fat, of which the material is composed. The term organic compounds was originally applied to those bodies which it was believed could be produced only as the result of life processes, but it is no longer used in that sense because many of the organic compounds are now produced in the laboratory by synthetic methods independent of life processes. The organic matter of a substance is obtained by subtracting the ash from the dry matter. The dry matter of wheat, for example, contains 2.10 per cent. ash and 97.90 per cent. organic matter. The organic matter of plant and animal bodies includes a number of classes and types of compounds.

224. Non-Nitrogenous and Nitrogenous Organic Compounds.—For purposes of study, the organic compounds of animal and plant bodies are divided into two large classes: (1) nitrogenous, and (2) non-nitrogenous. This division is made on the presence or absence of the element nitrogen. The nitrogenous or nitrogen-containing compounds are those in which the element nitrogen is in combination with carbon, hydrogen, oxygen, and small amounts of other elements, while the non-nitrogenous compounds are those which contain no nitrogen but are composed of carbon, hydrogen, and oxygen. Starch, sugar, and fat are types of non-nitrogenous compounds, while albumin, casein, and fibrin are types of the nitrogenous.

225. Classification of Non-Nitrogenous Compounds.—There are six large divisions of the non-nitrogenous compounds: (1) carbohydrates, (2) pectose substances, (3) fats, (4) organic acids, (5) volatile or essential oils, and (6) mixed compounds. Each division is, in turn, divided into various subdivisions and groups:

Organic non-nitrogenous compounds.

1. Carbohydrates,
   - Cellulose,
   - Starch,
   - Sugar,
   - Pentosans,
   - Gums.
2. Pectose substances (jellies).
3. Fats
   1. Olein,
   2. Stearin,
   3. Palmitin, etc.
4. Organic acids
   1. Tartaric,
   2. Oxalic,
   3. Malic, etc.
5. Volatile or essential oils.
6. Mixed compounds.

Carbohydrates

226. General Characteristics.—The carbohydrates are the first subdivision of the non-nitrogenous compounds, and include the starches, sugars, gums, and cellulose and pentosan bodies. They form the largest group of organic compounds in plants, and in many plants and food materials, are present largely as starch. The carbohydrates occur in plants in three physical forms: (1) As the framework of the plant cells, as cellulose, (2) in solution in the plant sap, as sugar, and (3) deposited as solid substances within the plant cells like starch. In coarse fodders, as hay, they are largely in the form of cellulose and pentosan bodies. While the various carbohydrates differ chemically and physically, they all possess a few common characteristics: (1) they are all neutral bodies, and (2) they all contain twice as many hydrogen as oxygen atoms in their molecules. The H and O are present in the same proportion as found in water, *viz.*, 2 atoms of H and 1 of O. In starch, $C_6H_{10}O_5$, the H and O would form $5H_2O$.

Cellulose

227. Occurrence.—Cellulose is found most abundantly in the stems, roots and leaves of plants, particularly at maturity. Cellulose is the structural basis of the vegetable world, and forms the framework of every plant cell. In some plants it is the most abundant material present; in hay and coarse fodders it makes up from 30 to 40 per cent. of the dry matter. Crops like cotton, flax and hemp contain large amounts, and are cultivated mainly for the cellulose which they yield.

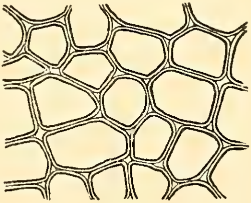


Fig. 72.—Cell structure of plant tissue.

228. Physical Properties.—Pure cellulose is a colorless, insoluble material, differing in texture according to its source. In hemp, it is flexible and tenacious, while in wood, it is hard and compact, in the pith of the elder, it is elastic, in the potato, porous, and in germinating seeds, loose and spongy. Cotton and filter-paper are examples of nearly pure cellulose. The proportion and properties of cellulose in a food influence its digestibility. Some foods are less valuable because of the tenacious character of the cellulose, which prevents the cells from undergoing disintegration and digestion.

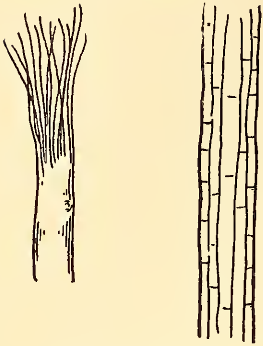


Fig. 73.—Flax fiber.

229. Chemical Properties.—Cellulose is composed of carbon, hydrogen and oxygen. Its formula is $C_6H_{10}O_5$. Cellulose from one source may contain a different multiple of $C_6H_{10}O_5$ than that from another source. In young and growing plants, the cellulose is in a hydrated condition; that is, water is chemically united with the cellulose molecule, as $(C_6H_{10}O_5.H_2O)_n$. Hydrated cellulose is more readily acted upon by chemicals than are other forms. As the plant develops, the cellulose is gradually dehydrated and this is one reason why cellulose, at different stages of growth, has a different food value. Ligno-cellulose is found in wood and many mature plants. It contains a larger per cent. of carbon than cellulose.

230. Function and Value.—In the plant, the function of cellulose is to form the structural part of the cell walls. It constitutes the main part of the walls of every plant cell.

In seeds, it is a reserve material, finally used as food by the young plant. Commercially, cellulose is used for making paper, cloth, guncotton and other explosives, and is extensively used in the arts.

231. Food Value.—The food value of cellulose depends upon its degree of hydration. Hydrated cellulose, when digested, has practically the same food value as starch. Lignocellulose is indigestible, and has no food value. Indirectly, a minimum amount of cellulose imparts a mechanical value to a food by acting as an absorbent for concentrated waste products. When crops are cut and cured while some of the cellulose is in a hydrated condition and but little has passed into the ligno form, the cellulose is valuable as food.

232. Amount of Cellulose in Plants.—Cellulose is found more abundantly in the stems and leaves of plants than in the seeds. In the straw of wheat, oats, rye, and barley, it makes up from 35 to 45 per cent. of the dry material. It also constitutes a large portion of the roots of plants. In seeds, the amount of cellulose is small, and usually ranges from 2 to 5 per cent., while in wood, the amount is large, and ranges from 50 to 80 per cent. In tables of analyses, the cellulose is usually included with other bodies under the head of crude fiber.

233. Crude Fiber.—Crude fiber includes the cellulose, lignin and other bodies which make up the framework of vegetable substances. In vegetable foods, as flour and the cereal products, the amount of crude fiber is small compared with that in many other plant bodies. Crude fiber and cellulose are not identical terms. In the chemical analysis of plants, the crude fiber is determined by first digesting the material in dilute sulfuric acid to dissolve all soluble bodies as sugar, hydrolyzed starch, some of the proteids and related bodies. The substance is then digested with dilute sodium hydroxid to remove all compounds which have failed to dissolve in the acid. Crude fiber and insoluble mineral matter are about the only substances which are insoluble in the dilute acid and alkali, hence the fiber is obtained by dissolving all other compounds and deducting the insoluble mineral matter left. For the determination of cellulose more exact methods have been devised. The crude fiber determination, however, is valuable because it shows the amount of fibrous material contained in plants.

Experiment 45.—Preparation of cellulose. Place in a beaker about 1 gram of ground straw or hay; add 200 cc. of water, and 20 drops of H_2SO_4. Boil on the sand-bath twenty minutes, and after the material settles, pour off the liquid, then add 100 cc. water, and wash thoroughly by decantation. Add 200 cc. water and 4 cc. NaOH solution, boil twenty minutes, and wash the fibrous material as before. Place some of the crude fiber in a test-tube, add 5 cc. HCl, 10 cc. H_2O, and a crystal of $KClO_3$; heat, and then wash the cellulose product.

Questions. (1) What element was liberated by the action of HCl upon the $KClO_3$? (2) What effect did this element have in the bleaching and purification of the crude fiber? (3) In what other experiment has this element been used as a bleaching reagent? (4) When examined with a lens, how did the cellulose appear? (5) Is cellulose soluble in dilute acids? (6) Why were the dilute acid and alkali solutions used in this experiment? (7) What becomes of the ash or mineral matter in the material used in this experiment? (8) What does this experiment show in regard to the properties of cellulose?

Starch

234. Occurrence.—Starch is found most abundantly in the seeds, roots, and tubers of plants, being stored up in those parts which are concerned with new growth. During growth, starch is produced in the leaves of all green plants; at maturity, it is stored in the seed or tuber. It is present in the plant cells as granules which have regular organized forms.

235. Physical Properties.—The starch granules from a given cereal are always constant in form and physical properties. Each grain is composed of overlapping layers which can be observed under the microscope. The walls of the layers are composed of a material called "starch cellulose"; between the walls is the pure starch known as granulose. All starch grains have a somewhat similar general structure. Starch is insoluble in cold water, because the walls of starch cellulose prevent the water from dissolving the pure starch. In hot water some of the granulose is dissolved and a paste is formed. Pure dry starch is tasteless and odorless. Starch is exceedingly hydroscopic, and commercial starch always contains from 10 to 12 per cent., or more, of water. A food which contains a large amount of starch will vary in moisture content and weight according to the hydroscopicity of the air. The starch grains obtained from different cereals and food products vary in form according to the source from which they are obtained. Wheat starch is circular in outline, and has a slightly concave center. There are but few markings or rings (see Fig. 74). The granules vary in size from 0.05 to 0.01 millimeter in diameter. Cornstarch is somewhat smaller (0.02 to 0.03 millimeter), more angular than wheat starch, and has a star-shaped center or helium (see Fig. 75). Oat starch is composed of a number of small segments forming a compound grain, or mass, each segment in itself a complete structure. Barley and rye starch grains are somewhat similar to wheat. In some vegetables, as the parsnip, the starch grains are minute.

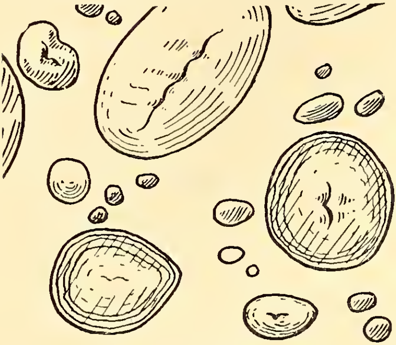


Fig. 74.—Wheat starch.

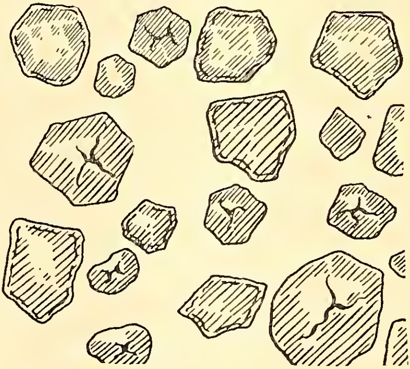


Fig. 75.—Cornstarch.

236. Chemical Properties.—Starch is composed of carbon, 44.44 per cent.; hydrogen, 6.17 per cent.; and oxygen, 49.39 per cent. Its formula is $(C_6H_{10}O_5)_n$. The value of *n* has been variously estimated from 2 to 200. The different starch grains, as of wheat, corn and oats, are all composed of the same elements, C, H, and O, and differ in form because these elements are put together in a different way in each. When acted upon by heat, as in the popping of corn, the starch grains are ruptured. At a temperature above 120° C., starch is changed to dextrin. In the presence of water and dilute acids, starch gradually undergoes hydration ; that is, water is chemically added to the molecule. By the joint action of heat, ferments, and various chemicals, starch is converted into a number of products, as soluble starch and dextrose. In the presence of iodin, starch is colored blue, different kinds of starch giving different shades and tints. The nature and mechanical form of the starch granules in a food, determine, to a slight extent, its rapidity and ease of digestion. Some starches are more easily digested than others, and all undergo important chemical and physical changes in the cooking and preparation of food. Since starch makes up such a large portion of many human and animal foods, its composition, properties, and food value are of prime importance.

237. **Function and Value.**—In the seed, starch is a reserve form of food for the use of the young plant before it is able to obtain its own food ; in roots and tubers also, it is stored up for that purpose. Many crops, as potatoes, corn, and sago, contain so much starch that they are often cultivated for starch-making purposes. Starch is obtained mechanically from potatoes by first pulping to break the cells, and then washing the pulped mass

with water from which the starch slowly settles. In the arts, starch is used in many ways. As a food, it is used mainly in its original form associated with the other organic compounds with which it is found in plants.

238. Food Value of Starch.—Starch is a valuable nutrient, and when digested produces heat and energy. When burned in the bomb calorimeter 1 pound of digestible starch produces 1860 calories. A calorie is the unit employed for measuring heat, and is the amount of heat required to raise 1 kilo of water 1° C., or approximately 1 pound of water 4° F. One gram of starch yields 4.2 calories. Pure starch alone is incapable of sustaining life because it contains no combined nitrogen, and does not supply any material for repairing the tissues of the body or for the construction of new nitrogenous tissue. When associated with nitrogenous compounds, starch can be used by the body for the production of fat as well as for the production of heat and energy.

239. Amount of Starch in Plants.—In grains, the amount of pure starch ranges from 50 to 75 per cent. of the dry weight of the material; in hay and forage crops, it is small, usually less than 2 per cent. The amount of pure starch in some of the cereals and farm crops is approximately as follows:

	Pure starch. Per cent.
Wheat	68
Wheat flour	72
Oats	55
Corn	75

	Pure starch. Per cent.
Rice	78
Potatoes	80
Wheat bran	8
Straw	less than 1
Hay	1 to 3

Experiment 46.—Preparation of potato starch. Reduce one or two clean potatoes to pulp on the grater. Tie the pulp in a clean cloth and squeeze into a large cylinder filled with water, occasionally dipping the bag into the water. Allow the cylinder to stand for twenty minutes, or until the starch has all settled; pour off the water. If the starch is not clean, wash by adding more water, and allow it to settle again; then pour off the water. Leave the cylinder in the desk until the starch is dry. Save this starch for the following tests:

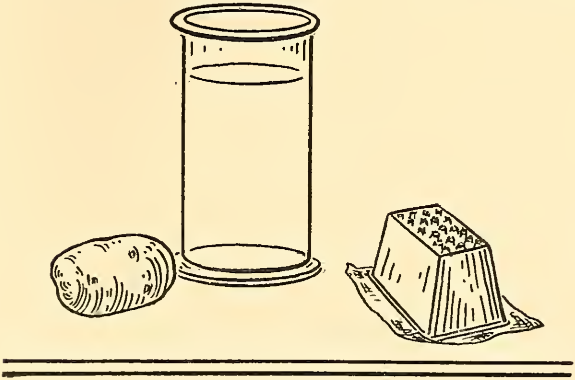


Fig. 76.—Obtaining starch from potato.

Tests for starch. Place 0.5 gram of starch in a test-tube about one-half full of water. Shake the test-tube, boil, and filter; then to this filtrate add a few drops of iodin.

Questions. (1) What was the difference in theaction of hot an cold water upon starch? (2) How did this difference show itself in the tests? (3) Why in the one test-tube were there a blue mass and a clear liquid, and in the other opposite results?

240. Dextrin is a carbohydrate which has the same general formula as starch from which it differs in structural composition. Dextrin is produced from starch by the action of heat. At a temperature of 163° C. moist starch is changed to dextrin. When this change takes place, nothing is added to or taken from the starch molecule. The three elements, C, H and O, are simply rearranged in a different way in the new molecule. Dextrin is not found naturally in food products to any appreciable extent, but is present in starch-containing foods which have been subjected to the action of heat. The brown crust of bread is composed mainly of dextrin. Dextrin is soluble in water, and is more readily digested than starch, but has the same general fuel and energy-producing value.

Experiment 47.—Preparation of dextrin. Place about 2 grams of flour in a porcelain dish; heat cautiously on a sand-bath for five minutes constantly stirring, so that it will not burn. When cool, add three times its bulk of water and heat nearly to boiling; observe the appearance of the solution; then filter. The filtrate contains dextrin. To a portion, add twice its bulk of alcohol; the dextrin is precipitated. To another portion, add a few drops of iodin solution; blue color indicates soluble but unaltered starch.

Questions. (1) What agent was employed to change the starch to dextrin? (2) How does dextrin differ from starch in solubility? (3) Is dextrin soluble in alcohol? (4) In what ways does dextrin differ from starch?

241. Structural Formulas.—Cellulose, starch, dextrin and inulin have the same general formula $(C_6H_{10}O_5)_n$, but all differ in both physical and chemical properties. This is because the elements, C, H and O, are put together in different ways in the three compounds. For example, a pile of bricks may be put together to form one structure, and then again in different ways to form other structures; in each structure there are the same number and kinds of bricks. So in the molecules of starch, dextrin, inulin and cellulose, there are the same number and kinds of atoms, but in each they are combined in a different way. In the study of the composition of plants, organic compounds are frequently met with which have the same general composition, but different chemical and physical properties. Whenever two compounds have the same general formula and percentage composition, but different chemical and physical properties, the difference is said to be one of structural composition.

Sugar

242. Classification of Sugars.—As commonly used, the term sugar is applied to the product obtained from sugar-cane or sugar-beets. As used in chemistry, it includes a large class of compounds of which maple-, cane-, and beet-sugar are examples of only one division. The two main classes of sugars present in plant bodies are sucrose and dextrose; occasionally, other sugars are found.

The sucrose group includes cane-, beet-, maple-, milk-, and malt-sugar. These sugars have the general formula $C_{12}H_{22}O_{11}$, and are characterized by the molecule containing 12 atoms of carbon. The dextrose group includes glucose, levulose, galactose, and all sugars having the general formula $C_6H_{12}O_6$. This group is characterized by the molecule containing 6 atoms of carbon. The term monosaccharide is applied to the dextrose group, and disaccharide to the sucrose group.

243. Occurrence of Sucrose.—Sucrose is found in plants in largest amounts of any of the sugars. Juices from the sugar-cane and sugar-beet contain from 12 to 18 per cent. It is also present in small amounts in seeds and cereal products. From 1.5 to 2 per cent. is found in sweet corn and about 0.50 per cent. in wheat flour. In some fruits, as apples, sucrose is present to the extent of 5 per cent. or more.

244. Physical and Chemical Properties of Sucrose.—The chemical and physical properties of sucrose obtained from the sugar-cane or sugar-beet are alike in all respects. When the two sugars have been subjected to the same degree of refining, they are identical. When examined under the microscope, sucrose is in the form of regular crystals, as shown in the illustration (see Fig. 77). At 160° C. sucrose crystals melt, and when cool form a colorless, glassy mass. A concentrated solution boils at a little above 100° C. At 160° C. a brown product known as barley sugar is formed. At 200° C. sucrose is decomposed, and gases, as carbon monoxid, carbon dioxid and methane, are given off. In concentrated solutions, a temperature of 100° C. causes an inversion; that is, the sucrose molecule is split up and two new sugars are formed, namely: dextrose and levulose. Hence, in the refining of sugar, the concentration must be carried on in vacuum

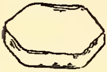


Fig. 77.—Sucrose crystal.

pans. In the presence of all acids, even dilute organic acids, hydrolysis or inversion of sucrose takes place.

245. Milk-Sugar (lactose) is found in cow's milk to the extent of 4.5 to 5 per cent., and is present in the milk of all mammals. It has the same general but a different structural composition from sucrose.

246. Maltose is a sugar produced in the malting of barley and other grains by the action of ferments upon starch, the reaction being

$$2C_6H_{12}O_6 = H_2O + C_{12}H_{22}O_{11}.$$

Maltose is not found to any extent in plant bodies, but is present in prepared foods which have undergone the malting process.

247. Inversion of Sucrose.—When sucrose is acted upon by heat and dilute acids, as well as other chemicals, inversion takes place. One molecule of water is chemically united to one molecule of sucrose which splits up and forms the two sugars, levulose and dextrose.

$$\overset{\text{Sucrose.}}{C_{12}H_{22}O_{11}} + H_2O = \overset{\text{Levulose.}}{C_6H_{12}O_6} + \overset{\text{Dextrose.}}{C_6H_{12}O_6}.$$

This process takes place in the ripening of fruits and in the curing of many fodders, as well as in the cooking and preparation of human foods.

Experiment 48.—Inversion of cane-sugar. Place 2 grams sugar, 30 cc. H_2O, and 2 cc. H_2SO_4 in an evaporator. Heat fifteen minutes on a sand-bath, replacing the water lost by evaporation. Neutralize with $CaCO_3$ and filter, adding more water if necessary for filtration. Test 5 cc. of the filtrate with an alkaline solution of copper sulfate (Fehling's solution) as directed in Experiment 34. Take 0.1 gram of sugar, dissolve in 10 cc. cold water, add 2 cc. alkaline copper sulfate solution, and heat cautiously for about a minute. Cane-sugar, unless inverted, gives no reaction with copper sulfate solution. Compare this result with the first test. Observe that in the first test the same precipitate is obtained as in Experiment 34.

Questions. (1) What is meant by inversion of cane-sugar? (2) Why was hot sulfuric acid used? Write the reaction. (3) Why was $CaCO_3$ used? (4) What becomes of the calcium salt when the solution is filtered? (5) What was the result when the filtrate was heated with alkaline copper sulfate solution (Fehling's solution)? (6) Did the sucrose, when tested, give any reaction with this reagent? (7) Under what condition in nature does this process of inversion take place? (8) What are invert sugars?

248. Refining of Sugar.—At the present time, the larger portion of commercial sugar is obtained from sugar-beets. In the diffusion process of manufacture, the beets, after cleaning and slicing, are passed into large tanks, where they are subjected to water under pressure which removes the sugar by liquid diffusion. The impurities associated with the sucrose are precipitated with lime water, $Ca(OH)_2$, the excess of lime being removed by carbon dioxid gas which converts the calcium hydroxid into insoluble calcium carbonate. For the purpose of producing the pure lime and the carbon dioxid gas, limestone is burned in specially constructed kilns at the sugar factory. After the removal of the impurities and lime, the solution containing the sugar is concentrated in a large vacuum pan and allowed to crystallize; the crystals are then washed in centrifugal washing machines and granulated. Commercial sugar is ordinarily about 99 per cent. pure sucrose.

249. Occurrence of Dextrose.—Dextrose occurs widely distributed in nature. It is found in small amounts in the sap of saccharine plants, in seeds, ripe fruit, honey, animal tissues, and all food products in which the sucrose has undergone inversion.

250. Chemical and Physical Properties.—Dextrose is a solid, white substance which gives off water from its molecule when heated to 170° C. At 200° C., volatile gases and acid products are formed. Acids and alkalies act upon dextrose and produce a large number of compounds. Dextrose is capable of undergoing a number of different kinds of fermentation, alcohol, succinic acid, lactic acid, and glycerol being some of the products formed. Whenever foods which contain dextrose are exposed to favorable conditions, fermentation takes place. Dextrose is produced commercially by the action of dilute acids upon starch. The acid causes a molecule of water to unite chemically with a molecule of starch.

$$C_6H_{10}O_5 + H_2O = C_6H_{12}O_6.$$

The thick syrup that is formed after the acid is neutralized is called glucose syrup. If a solid mass is produced, it is called grape-sugar.

Experiment 49.—Preparation of glucose. Add 20 drops H_2SO_4 to about 70 cc. water in an evaporator. Heat on the sand-bath until the boiling-point is reached. Then add 2 grams of pulverized starch. Observe the appearance of the starch immediately after adding. Heat twenty-five minutes, stirring occasionally, and replacing the water should too much evaporate. Add $CaCO_3$ to neutralize the H_2SO_4; when neutral to test paper, filter, washing the contents of the filter with 25 cc. of water. Take a few drops of the filtrate and test with iodin for starch. Then evaporate the rest of the filtrate to about 20 cc. and observe its appearance.

Tests for glucose. Place about 3 cc. of glucose solution in a test-tube, add 3 cc. alkaline solution of copper sulfate, called Fehling's solution (see Experiment 34), and heat. Then take about 0.1 gram of glucose from the shelf bottle, dissolve it in 5 cc. water, add 3 cc. Fehling's solution. Heat, and compare with the first test.

Questions. (1) Why was sulfuric acid used in this experiment? (2) What chemical change did the starch undergo? Write the reaction. (3) Why was $CaCO_3$ used? Write the reaction. (4) Was any reaction obtained with iodin for starch? (5) What was the result when the glucose solution was added to the hot alkaline solution of copper sulfate? (6) How did this precipitate compare with that obtained when glucose from the shelf bottle was used?

251. Levulose, commonly called fruit-sugar, is formed along with dextrose whenever sucrose undergoes inversion. It has the same formula as dextrose, $C_6H_{12}O_6$, but different chemical and physical properties, due to a different structural composition. Levulose is very sweet, and is found in many ripe fruits and vegetables. Its properties are somewhat similar to those of dextrose, but it is more susceptible to the action of heat, acids, and alkalies, and less to the action of ferments.

Experiment 50.—Levulose and reducing sugars from carrots. Reduce a small clean carrot to a pulp. Place the pulp in a beaker and add 200 cc. water. After half an hour, filter, heat the filtrate for fifteen minutes and then filter a second time. Evaporate 50 cc. of the filtrate nearly to dryness. Test a portion with Fehling's solution as in Experiment 49.

Questions. (1) How was sugar separated from the carrots? (2) What was the result when the filtrate was heated, and what compounds were precipitated? (3) Describe the appearance of the concentrated filtrate. (4) What reaction was obtained with Fehling's solution? (5) How does levulose differ in composition and properties from dextrose?

252. Miscellaneous Sugars.—A number of sugars that do not belong to either the dextrose or sucrose group are found in plants. Raffinose, for example, is a sugar found in small amounts in beets and other vegetables. It is capable of being converted into dextrose sugars by treatment with dilute acids.

253. Optical Properties of Sugar.—Sugars are characterized as optically active or inactive. Those which have the power of turning a ray of polarized light to the right are called dextrorotatory while those which turn the ray to the left are called levorotatory. Polarized light has no action upon the inactive sugars. This principle is taken advantage of in the commercial testing of sugar by means of the polariscope which is a piece of apparatus so constructed that the number of degrees which a ray of polarized light is diverted in passing through a solution of sugar can be accurately measured, and the purity of

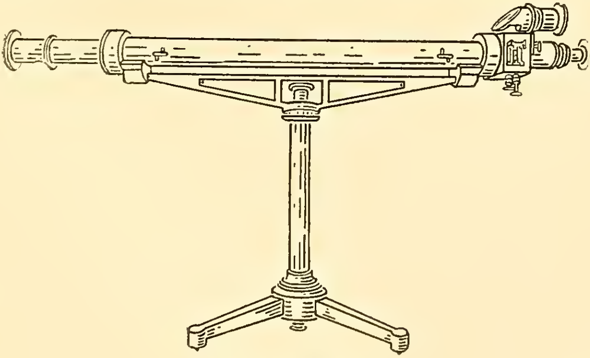


Fig. 78.—Polariscope.

the sugar determined. A given weight of pure sucrose dissolved in a definite amount of water always turns a ray of polarized light a definite number of degrees which are accurately measured by the polariscope. Any decrease in purity influences proportionally the angle of divergence of the polarized light. Hence, if the angle of divergence of a commercial sugar is determined, its purity is likewise determined.

254. Sugar-Beets are usually paid for on the basis of their content of sugar and the purity of the juice. For sugar-making purposes, the higher the content of sugar and the purer the juice, the more valuable the beets. Ordinarily, sugar-beets contain from 12 to 16 per cent. sugar; occasionally as low as 8 and as high as 20 per cent. In addition to sugar, the beet juice contains other solids, as small amounts of organic acids, albumin and pectin. When the content of solid matter is 20 per cent. and 16 of the 20 parts are sugar, the juice has a purity coefficient of 80 ($^{16}/_{20} \times 100$).

255. Food Value of Sugar.—When properly combined and used with other foods, sugar is a valuable nutrient for the production of heat and energy. Like starch, it is incapable of sustaining life unless associated with nitrogenous compounds. One pound of sugar, when burned, yields 1.5 pounds of carbon dioxid and 0.58 pound of water.

$$C_{12}H_{22}O_{11} + 24O = 12CO_2 + H_2O.$$

In a ration, sugar is considered as having the same caloric value as starch, *viz.*, 1 pound yields 1860 calories.

256. Gums.—Closely related to the sugars are the gums, like gum arabic, and those which exude from peach and cherry trees. In the seeds of many grains, there are also gum-like bodies. When treated with dilute acids, the gums are converted into dextrose sugars and acid products. Bassorin, or mucilage, as flaxseed mucilage, is found in a few seeds and fruits. The formula for some of the gums is the same as for sucrose sugars and dextrose.

257. Pentosans.—The pentosans are a class of carbohydrates present in liberal amounts in many plants. They are insoluble, and aid the cellulose in giving form and structure to plant tissues. When acted upon by dilute acids, the pentosans are rendered soluble, while true cellulose is insoluble. They are called pentosans because they yield a sugar which contains five atoms of carbon in the molecule. When acted upon by the digestive fluids they are rendered soluble and available as nutrients. In some fodders they form a large part of the nitrogen-free extract. The digestible pentosans are considered as having the same food value as other digestible carbohydrates. The amount of pentosans in some common foods is approximately as follows:

	Per cent.
Hay, timothy	20
Linseed meal	12 to 15
Wheat bran	17 to 22
Wheat	4 to 6
Oats	12
Corn	5
Barley	5 to 7
Flour	trace

258. Peptin Bodies are present in many ripe fruits and vegetables. They are jelly-like substances, which are soluble in hot water, and are commonly known as fruit jellies. When treated with dilute acids, digestive fluids, and other reagents, the pectin bodies are converted into dextrose sugars and other products. Potatoes, turnips, beets, and all fruits contain pectin. In unripe fruits, and in some uncooked vegetables, the pectin is in the form of acid bodies which are insoluble and indigestible. In the last stages of ripening, the pectin of fruits and vegetables undergoes a change to soluble forms. Soluble pectin is considered to have the same food value as the soluble carbohydrates.

Experiment 51.—Pectose from potatoes. Reduce a small clean potato to a pulp. Squeeze the pulp through a clean cloth into a beaker, add 10 cc. H_2O, and heat on a sand-bath to coagulate the albumin. Filter, add a little hot water if necessary. To the filtrate add a little alcohol. The precipitate is the pectose material.

Questions. (1) Is the pectose from the potato soluble? (2) Is pectose coagulated by heat? (3) Is it soluble in alcohol? (4) In what ways does pectose differ from sugar? (5) In what ways does it resemble sugar?

259. Nitrogen-Free Extract.—In the processes of chemical analysis of plants and foods, the chemist determines the water, ash, crude protein, ether extract, and crude fiber, and classes the remainder in one group or division called nitrogen-free extract. Wheat, for example, contains:

	Per cent.
Water	9.25
Ash	2.95
Crude protein	13.25
Ether extract	2.20
Crude fiber	2.25
Total	29.90

100 — 29.90 = 70.10 per cent. nitrogen-free extract.

The term nitrogen-free extract means that the bodies contain no nitrogen ; they are nitrogen-free or non-nitrogenous, and are soluble in dilute acids and alkalies. The nitrogen-free extract of wheat is composed mainly of starch ; in some foods, as carrots, it is largely sugar. In human foods, the nitrogen-free extract is composed mainly of carbohydrates as starch and sugar, while in animal foods, it consists of pentoses and a large number of compounds dissimilar in character and food value. In plant bodies, the nitrogen-free extract usually constitutes the largest of any of the groups of compounds. Meats and animal products, except milk, contain only very small amounts.

Fats

260. Presence in Plants.—Fats and oils form one of the subdivisions of the non-nitrogenous compounds of plants. Fat is present in nearly all plants, but in smaller amounts than the carbohydrates. The fat in plants is produced from starch. For example, in flax, there is more starch than fat when the plant is growing, but in the mature plant, there is more fat than starch, due to the starch being converted into fat. This change of starch to fat can take place only in the plant cells ; fat, as yet, cannot be made synthetically. During the process of germination, the fat of seeds is changed back to starch. While fat is present in nearly all parts of plants, it is found most abundantly in the seeds, as of flax, rape and cotton, which are often called oil seeds. Fat occurs in the form of minute oil globules within the plant cell, and is removed mechanically by the aid of heat and pressure, as in the manufacture of linseed, rape, cottonseed and other oils. It is also extracted by means of solvents as benzine and carbon disulfid. In roots and stems, fat is found only in traces. In leaves, it is often present in the form of a waxy coating, while in nuts it is frequently stored up in large amounts in the kernel.

261. Physical Properties.—Fats are all characterized physically by being insoluble and of a lower specific gravity than water. There are a great many separate fats, and each has its own specific gravity and melting-point. As commonly found, they are not simple bodies, but mechanical mixtures of various separate fats, as stearin, palmitin, and olein. The fats are all soluble in ether, chloroform and turpentine, and differ in physical properties according to the proportion and kind of fats present. When examined under the microscope, some have optical properties and definite crystalline forms.

262. Chemical Composition.—Fats are all characterized by having a high per cent. of carbon and a low per cent. of oxygen. For example, in stearin $C_{57}H_{110}O_6$, there are in the molecule 57 atoms of carbon, and 6 atoms of oxygen. In starch and carbohydrates in general, the per cent. of oxygen is greater, and of carbon, less than in fats.

ULTIMATE COMPOSITION OF FATS.

	Stearin. Per cent.	Palmitin. Per cent.	Olein. Per cent.	Starch. Per cent.
Carbon	77.6	75.9	77.4	44.44
Hydrogen	12.4	12.2	11.8	6.17
Oxygen	10.0	11.9	10.8	49.39

Fats are organic salts, the basic part consisting of the glycerol radical C_3H_5 which is combined with a fatty acid. Glycerin is the basic constituent common to all fats. One fat, as stearin, differs from another, as olein, by containing a different fatty acid in combination with the glycerol radical. When the simple fats are separated into their component parts, the acids formed are: stearic, palmitic, oleic and butyric.

Some of the fatty acids, as stearic and palmitic, are solids, while others, as butyric, are volatile. Those fatty acids which distil with boiling water are called volatile fatty acids. Butter, for example, contains nearly 5 per cent. of volatile fatty acids, present mainly in the form of butyric acid. Some of the fats undergo fermentation and become rancid, as butterin in butter, while others slowly take up oxygen from the air and undergo oxidation. The chemical and physical properties of the fats in plants and foods are determined by the kinds and amounts of the separate fats present. Olein, stearin and palmitin are always present in larger amounts than are other fats.

263. Stearin ($C_{57}H_{110}O_6$) is a solid fat with a high melting-point, 69.4° C. Beef and mutton tallow and animal fats in general are composed mainly of stearin. When pure, it is a white and tasteless body, and has a definite crystalline structure. Stearin predominates in all hard fats.

264. Palmitin ($C_{51}H_{98}O_6$) is a white, solid fat obtained from butter, palm oil and human fat. When chemically pure, it is tasteless, and crystallizes in the form of tufts and needles. It has a melting-point of 63° C. Its general properties are somewhat similar to those of stearin.

265. Olein ($C_{57}H_{104}O_6$) at moderate temperatures is a liquid. It solidifies at 4° C. Olein predominates in the oil of fish, as sperm oil and cod-liver oil. It is also present to a great extent in many vegetable oils, as olive oil. Whenever olein predominates, the fat is a liquid.

266. Miscellaneous Fats.—In addition to the three fats mentioned, there are others, as butyrin, the characteristic fat of butter, and linolein, the characteristic fat of flaxseed.

267. Saponification is a chemical change brought about by the action of an alkali, as potash or soda, upon a fat. An exchange takes place between the glycerol of the fat and the metal of the alkali. Glycerine is a base, but potash is a stronger base ; hence the potash replaces the glycerol and forms salts, as potassium stearate or palmitate, according to the fat used.

Experiment 52.—Saponification. Weigh about 20 grams of lard into an evaporator. Melt the lard, but do not heat above 50° C. Dissolve 10 grams NaOH in about 40 cc. water in a beaker. (Do not let the NaOH come in contact with the scale pan.) Add this solution to the evaporator, stirring constantly, and leave the evaporator on the warm sand-bath, with a low flame underneath, for 40 to 50 minutes. Then place on the sand-bath in the desk until the following day when a good soap should have formed. Dissolve a little of the soap thus produced in a test-tube with 20 cc. water. Divide the solution into two parts ; to one add a little salt, and to the other a few drops of HCl.

Questions. (1) Why was NaOH used in this experiment, and what portion of the fat did it replace? (2) What other materials could be used in place of NaOH? (3) What influence did the salt have upon the soap solution? (4) What was the result when HCl was added to the soap solution? (5) Why is it necessary to weigh both the lard and the NaOH? (6) What would be the result if the fat and alkali were taken in different proportions from those used in this experiment? (7) Why does soap form an insoluble mass with hard waters?

268. Fatty Acids.—Formic acid, found in pine needles and in red ants, has the formula H_2CO_2 which is also written HCO_2H. Acetic acid has the formula $H.CH_2.CO_2H$, and differs from formic acid simply in containing CH_2 more than found in formic acid. If CH_2 were added to acetic acid, $H.C_2H_4.CO—H$, propionic acid would be produced. This is present in some plants. In like manner, butyric acid can be produced from propionic acid. By the addition of CH_2, about twenty acids can be formed in the way described. This list includes palmitic, stearic and other acids found in fatty bodies and named fatty acids; various of these are present in nearly all foods. When a series of compounds, like the fatty acids, shows a uniform difference between two adjacent members the term homologous series is employed.

269. Waxes.—Wax is similar in composition to fat, but contains an ethyl radical in place of the glycerol radical. Beeswax, for example, is composed of palmitic acid and ethyl radicals. Waxes, like fats, undergo saponification and are considered as having the same food value.

270. Food Value of Fat.—Fat is the most concentrated non-nitrogenous nutrient of foods. On account of containing such a large amount of carbon and small amount of oxygen, fat, when either burned or oxidized as food, produces 2.25 times more heat than the same weight of starch or sugar. One gram of fat yields 9.2 calories, and 1 pound, 4225 calories. The fact that so much more heat is produced from the oxidation of fat is apparent when the products of oxidation of starch and fat are compared.

Stearin.

$$\underset{890}{C_{57}H_{110}O_6} + 163\ O = \underset{2508}{57CO_2} + \underset{990}{55H_2O}$$

1 pound of fat produces 2.8 pounds CO_2 + 1.1 pounds of water.

Starch.

$$\underset{162}{C_6H_{10}O_5} + 12\ O = \underset{264}{6CO_2} + \underset{90}{5H_2O}$$

1 pound of starch produces 1.6 pounds CO_2 + 0.56 pound H_2O.

890 parts, by weight, of fat produce, when burned, 2508 parts, by weight, of carbon dioxid and 990 parts of water. 162 parts, by weight, of starch produce 264 parts, by weight, of carbon dioxid and 90 parts of water. One pound of fat yields 2.8 pounds of carbon dioxid and 1.1 pounds of water, while one of starch yields 1.6 of carbon dioxid and 0.56 of water. Fat produces approximately 2.25 times more heat than starch.

271. Amount of Fat in Plants and Foods.—The amount of fat in various plant substances ranges from a few hundredths of a per cent. in tubers to 35 per cent. and more in flaxseed. Of ordinary grains, oats and corn are the richest in fat and contain from 3.5 to 5 per cent., while wheat and rye have about 2 per cent. each. In hay, the amount of pure fat is less than 2 per cent., and in straw it is less than 1 per cent. In nearly all food products, the per cent. of pure fat is included with the ether extract.

Experiment 53.—Fat from wheat germ. Place 2 grams wheat germ in a test-tube, and add gasoline until the test-tube is about one-third full. Cork and shake at intervals of three or four minutes. Do not let the gasoline come near the gas flame. Filter into a clean porcelain dish, and place the dish in an open window until the gasoline is evaporated. Observe the residue of fat.

Experiment 54.—Fat from yolk of egg. Repeat the preceding experiment, using one-fourth of the yolk of a hard boiled egg, and 5 cc. ether instead of gasoline.

Questions. (1) What was the solvent used for separating the fat from the wheat germ? (2) From the yolk of the egg? (3) Describe the fat obtained from the wheat germ. (4) From the yolk of the egg. (5) How were the solvents removed in these experiments? (6) Are fats volatile bodies? (7) Why do fats obtained from different sources vary in appearance and properties?

272. Ether Extract.—The term ether extract is applied to that class of compounds which is soluble in ether. In the case of human foods, the ether extract consists largely of fats and oils with variable amounts of waxes, resins, chlorophyl, vegetable coloring-matters and nitrogenous and phosphorized bodies as lecithin. The value of the ether extract depends entirely upon its source; in milk, meats, and cereals and their products, the ether extract is nearly pure fat, while in many vegetables it is less than half fat. Methods of chemical analysis have not, as yet, been sufficiently perfected to allow the separation and determination of the pure fat of all materials. The ether extract is obtained by placing a small weighed amount of the dry material in a tube, 3, (Fig. 79) which is then placed in a glass extractor connected with a small weighed flask containing ether. The flask is immersed in a water-bath heated by a gas burner, the ether is volatilized, and the vapor passes through openings 2 and 4 into the condenser where it is cooled and falls back in drops from point 4 on the substance at 5. The ether percolates through the substance and returns to the flask. The fats and ether-soluble matters are not volatilized but remain in the flask while the ether is vaporized and condensed again and again. After the extraction is completed, the ether is distilled from the flask, the ether extract dried and weighed, and the percentage amount calculated. While the process appears to be simple, it is a difficult operation to control, because even after many days' extraction, some materials will continue to give up ether extract, and unless unusual care is taken some of the fats are oxidized. Then, too, the ether extract is liable to be contaminated with impurities if ether of a high degree of purity is not used. When the determinations are made

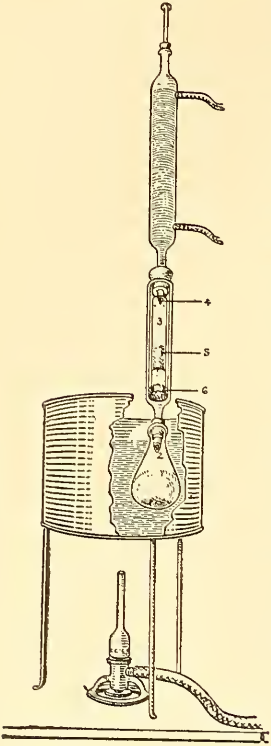


Fig. 79.—Ether extractor.

under uniform conditions, the results are comparable and are of value when properly interpreted.

Organic Acids

273. Occurrence in Plants.—In all plants and vegetable foods, there are present bodies known as organic acids. An organic acid, like all acids, contains hydrogen which can be replaced by a metal (see Section 75). The negative radical of the acid contains carbon, hydrogen, and oxygen. For example, in tartaric acid, $H_2C_4H_4O_6$, the H_2 can be replaced by a metal; $C_4H_4O_6$ is the tartaric acid radical. Organic acids, like mineral acids, are neutralized by bases.

$$2KOH + \underset{\text{Tartaric acid.}}{H_2C_4H_4O_6} = \underset{\text{Potassium tartrate.}}{K_2C_4H_4O_6} + 2H_2O.$$

As a rule, the organic acids are not present in a free state, but are combined with base-forming elements, as potassium and calcium, forming organic and acid salts. In plants, the organic acids are found mainly in solution, as in the sap. When the plant matures, they are used either for the construction of other organic compounds, or are neutralized by bases to form insoluble salts, as calcium oxalate, and deposited as crystals in the leaves. A small amount of acid is found in all mature seeds, and during germination, some of the carbohydrates are converted into acids. In green vegetables and small fruits, the organic acids are found more liberally than in the seeds of grains; in the leaves and stems of matured plants, but little acid is found. Some of the organic acids from fruits are of commercial value, as crude tartaric acid or argol found in grapes, and from which cream of tartar is prepared. There are a large number of organic acids found in plants and food materials, and in the study of organic chemistry; these acids constitute an important part. In this work, only a few of the more common organic acids are considered.

274. **Tartaric Acid** is the characteristic acid of grapes. It is also found in small amounts in pineapples, cucumbers and potatoes. It can be produced in the laboratory by the oxidation of milk-sugar and other carbohydrates. Crude tartar or argol, from which commercial cream of tartar is made, is deposited when grape juice ferments. When tartaric acid is neutralized with bases, tartrates are formed. Sodium potassium tartrate (Rochelle salt) is one of the most important salts of tartaric acid.

275. **Malic Acid** occurs in many vegetables and small fruits, as tomatoes, currants and strawberries. It is the organic acid which occurs most abundantly in small fruits. Malic acid can be produced from tartaric acid by the action of hydrochloric acid.

276. **Succinic Acid** is found in many plants, and also in animal tissues. Small amounts of this acid are formed when dextrose undergoes alcoholic fermentation. Succinic acid occurs also in soils, particularly those of a peaty character. It can be produced from malic acid by the action of hydrochloric acid. Chemically, the three acids, tartaric, malic and succinic, are closely related.

277. **Oxalic Acid** is found in small amounts in nearly all plants, particularly those of the oxalis variety. In

some plants, it is present in sufficient amounts to be poisonous. Oxalic acid can be produced, in the laboratory, by the action of nitric acid upon sugar and other carbohydrates.

278. **Nitric Acid** is present in lemons and many small fruits. It is found in small amounts in peas, beans, vetches, and lupines, and with malic acid in cherries, strawberries and currants.

Experiment 55.—Citric acid from lemons. Measure out with the pipette 10 cc. of the prepared lemon juice solution. Dilute with about 25 cc. distilled water, and add 5 to 7 drops phenolphthalein indicator. Then add standard KOH from the burette until a faint pink tinge remains permanent. One cc. KOH will neutralize 0.004 gram citric acid. How much citric acid is present? The lemon juice solution is prepared by diluting the clear lemon juice with ten times its bulk of distilled water and filtering.

Questions (1) Why was KOH used in this experiment? (2) What chemical change took place when KOH was added to the diluted lemon juice? (3) What change in color was observed? (4) What was the final product formed in this experiment? (5) How does this experiment compare in principle with Experiment 10?

279. **Tannic Acid.**—In many seeds and leaves of plants, bitter astringent compounds, as tannin and tannic acid, are found. They may lessen the value of a food because they retard the natural process of digestion. Tannic acid is not present in food plants in any appreciable amounts. Commercially, the tannins are valuable for the tanning of leather and for other purposes. Tannin-yielding plants are occasionally grown as marketable crops.

280. **Function and Food Value of the Organic Acids.**

—The organic acids of plants are valuable mainly because they impart palatability to foods and exert a favorable influence upon digestion by stimulating the secretion and flow of the digestive fluids. Many of the organic acids have medicinal properties, and some, as oxalic acid, are poisonous. The organic acids cannot be considered as heat- or flesh-producing nutrients, but simply as food adjuncts. In plants, they take an important part in the assimilation of the mineral elements of plant food, and the production of new tissue. The acid sap comes in contact with the soil particles, dissolving the plant food which is then absorbed by osmosis.

Essential Oils

281. General Properties.—The essential or volatile oils are the compounds which impart characteristic taste and odor to plants. They differ from the fixed oils or fats by completely volatilizing when heated, and leaving no permanent residue on cloth or paper. They also have an entirely different chemical composition from the fats.

282. Occurrence.—Volatile or essential soils are found, in some form, in nearly all plants, particularly during growth. In some fruits, and seeds, they impart the characteristic flavor and give individuality to the material. Oil of lemon, oil of cedar, and oil of nutmeg are examples of essential oils. In nearly every plant, one or more of the essential oils is present at some period of growth.

283. Chemical Composition and Properties.—The essential oils are mixed bodies, many of them belonging to the aromatic series of compounds (see Section 138). According to chemical composition, they may be divided into four groups, and each group in turn into a number of subdivisions.

Groups.	Examples.
1. Terpenes, $C_{10}H_{16}$	Oil of lemon, oil of turpentine.
2. Cedrenes, $C_{15}H_{24}$	Oil of cedar, oil of cubeb.
3. Aromatic aldehydes	Oil of cinnamon, oil of almond.
4. Etherical salts	Pineapple and fruit flavors.

The essential oils are separated from plants by distillation. At ordinary temperatures, most of them are liquids, insoluble in water, but soluble in alcohol. When the terpenes and cedrenes oxidize, they produce resinous deposits from which turpentine is obtained (see Section 135). The aromatic aldehydes form a homologous series beginning with benzoic aldehyde, $C_6H_5.CHO$, and are present in many plants and fruits, imparting flavor. Ethyl formate, $C_2H_5.HCO_2$, peach flavor, ethyl butyrate, $C_2H_5.C_4H_7O_2$, pineapple flavor, and amyl valerate found in apples, are some of the common etherical salts.

284. Essential Oils of Agricultural Crops.—When hay is cut, the odor produced is due to a volatile oil. This material is lost when the hay is overcured or exposed to leaching rains. The characteristic odor of clover, particularly pronounced in sweet clover, is due to an aromatic body. The odors of all fodder crops are imparted by characteristic essential oils. In the preparation of hay and fodder crops, it should be the aim to prevent, as far as possible, any loss of essential oils. This can be accomplished by cutting the fodder before it is overripe, and then avoiding bleaching and leaching. Rape, turnips, cabbage, parsley and onions contain essential oils.

285. Synthetic Production of Essential Oils.—Nearly all of the essential oils found in fruits, as pineapple flavor, peach flavor, and vanilla, are capable of being produced synthetically in the laboratory. They are definite chemical compounds, and it is only necessary to bring together, under the right conditions, the radicals or component parts for them to unite and form these compounds. Pineapple flavor is ethyl butyrate. The acid constituent of this salt, butyric acid, is found in stale butter, while the basic part of the radical is present in ether and alcohol. The chemical union of butyric acid and the ethyl radical gives ethyl butyrate or pineapple flavor. In fact, nearly all of the commercial fruit flavors are laboratory products. When properly made, they are identical with the same flavors as found in fruits, but frequently they contain traces of acid or alkaline products used in their preparation.

286. Amount of Essential Oils in Plants.—The amount of essential oils in plants and foods is small, less than 1 per cent. and usually only a fraction of a per cent. This small amount is, however, sufficient to give a characteristic taste.

287. Food Value.—Some of the essential oils of fodders, like the organic acids, exert a favorable influence upon digestion by imparting palatability and stimulating the secretion and flow of the digestive fluids. They are not heat- or muscle-forming nutrients, but simply food adjuncts. Some of the essential oils have medicinal properties, while others, as oil of bitter almonds, are poisonous.

Experiment 56.—Essential oil from tea. Place 0.5 gram tea into a small flask, and add 50 cc. water. Connect the flask with a delivery tube, one end of which leads into a test-tube containing

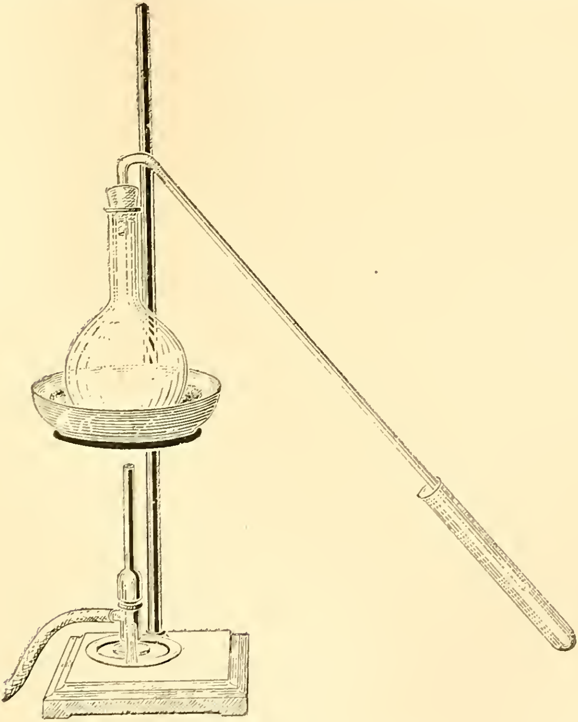


Fig. 80.—Preparation of essential oils.

water. Arrange apparatus as shown in Fig. 80. Apply heat and distil 3 to 5 cc. Observe odor of distillate which is the volatile oil of tea. Repeat this experiment, using sweet or red clover.

288. Miscellaneous Compounds of Plants.—Not all of the non-nitrogenous compounds present in plants are included in the subdivisions: carbohydrates, fats, organic acids and essential oils. The most important and more common ones are, however, included in the above list. There are a great many others which, for convenience of classification, are called miscellaneous or mixed compounds.

289. Relationship of Non-Nitrogenous Compounds of Plants.—A marked general relationship exists between many of the non-nitrogenous compounds. For example, the various carbohydrates are capable of undergoing chemical changes in which one form is changed to another. Starch can be converted into cellulose, sucrose, maltose or any other carbohydrate, and conversely cellulose can be converted into starch or other similar compounds. These changes take place during plant growth, particularly in the germination of the seed, and are brought about by the action of ferment bodies which cause either the addition or elimination of water from the molecule, as

$$2C_6H_{10}O_5 + H_2O = C_{12}H_{22}O_{11}.$$

Not all of these reactions can take place in the laboratory. Starch may be changed to glucose or maltose, and sucrose may undergo inversion and form invert sugars, but sucrose cannot be made in the laboratory; neither can starch or cellulose be made from glucose. During germination, some of the carbohydrates are converted into organic acids.

The fatty acids are the characteristic constituents of fats. In germinating seeds, fat is formed from starch by the addition of oxygen. The pectose substances are capable of being separated in the laboratory into glucose and acid products. Likewise the glucosides may be split up into glucose and acid bodies. In fact, the various non-nitrogenous compounds of plants, considered as a whole, are more or less related in chemical composition.

290. Food Value of the Non-Nitrogenous Compounds.—As a class, the non-nitrogenous compounds are valuable as heat- and energy-producing nutrients. They do not all have the same caloric or fuel value; for example, a gram of starch yields 4.2 calories while a gram of fat yields 9.2. As a rule, the more concentrated the compound is in carbon, the greater is its fuel value. When properly associated and combined with the nitrogenous compounds, the non-nitrogenous nutrients of plants may produce fat in the animal body. A few of the non-nitrogenous compounds, as the essential oils, have but little direct value as nutrients. Others, as some bitter principles and tannic compounds, may lessen the value of foods or impart a negative value. The carbohydrates, fats, and related non-nitrogenous compounds take an important part in the nutrition of man and animals, and many foods owe their value entirely to the fats and carbohydrates which they contain.

CHAPTER XXIV

Nitrogenous Organic Compounds of Plants

291. Amount of Nitrogenous Matter in Plants.—As a rule, less than 15 per cent. of the dry matter of plants is nitrogenous material. In the seeds of legumes, as beans and peas, this amounts to about 22 per cent. In nearly all plants, the non-nitrogenous compounds are from six to ten times more abundant than the nitrogenous.

292. Different Terms Applied to Nitrogenous Compounds.—Unfortunately, the various terms used to designate the nitrogenous compounds have not been uniformly applied. The terms nitrogenous compounds, proteids, crude protein, and albuminoids have been used synonymously, but each applies to a different class of bodies. The terms organic nitrogenous compounds and crude protein are the most satisfactory when applied to the entire group; proteids and albuminoids are subdivisions of the nitrogenous compounds.

293. Complexity of Composition.—The nitrogenous compounds are more complex in composition than the non-nitrogenous. The percentage composition and formulas of nearly all of the non-nitrogenous compounds of plants have been determined, and while the percentage composition and the physical and chemical properties of the more important nitrogenous compounds are known no definite formulas have, as yet, been applied because of the complexity of their molecular structure. The nitrogenous compounds are composed of carbon, hydrogen, nitrogen, and oxygen, and many contain in addition to these, phosphorus, sulphur and other elements.

294. Classification of Nitrogenous Compounds.— For food purposes, the nitrogenous compounds of plant and animal bodies may be divided into four groups: (1) Proteids, (2) albuminoids, (3) amides, and (4) alkaloids. There are a few nitrogenous compounds in plants that do not find a place in any of the above subdivisions.

Proteids

295. General Composition. — Proteids are complex nitrogenous compounds that contain about 16 per cent. of nitrogen and less than 2 per cent. of sulfur. The per cent. of the different elements in protein compounds from various sources ranges as follows:

	Per cent.
Carbon	51.2–54.7
Hydrogen	6.7–7.6
Nitrogen	15.2–18.0
Oxygen	20.2–23.5
Sulfur	0.3–2.0

It was believed, at one time, that all of the various compounds called proteids had, in common, a nitrogenous radical in their molecule to which the name protein was given, but this hypothesis has not been found correct. The term protein has been retained but without reference to the supposed protein radical.

296. Occurrence. — Proteids are found more abundantly in the seeds of plants than in the leaves or other parts, and are always present in the active living cells of both plants and animals. The proteids take an important part in life processes, protoplasm being largely of a proteid nature. In the growing plant, the proteids are found most abundantly in the leaves; at maturity, they are stored up in the seed for the future use of the embryo. The proteids occur either in a soluble form in the liquids of plant and animal tissues or in a semisolid, insoluble condition as a part of the tissues. The proteids from animal and plant sources are closely related, but are not in every respect identical. For food purposes, however, they may be jointly considered.

297. Physical Properties.—While the members of the proteid group differ materially, they all have certain physical properties in common. All are optically active and turn polarized light to the left. The soluble proteids, with the exception of peptones and proteoses, are coagulated by heat. The proteids show a wide range in solubility, but all are soluble in either acid or alkaline solutions. As a class, they do not crystallize, and are diffusible with the exception of the peptones and proteoses.

298. Chemical Properties.—In structure the proteid molecule is an exceedingly complex and unstable body. It is readily acted upon by ferments and chemicals. Nitrogen seems to form a weak link in the chain of elements. Proteids unite with acids and alkalies to form acid and alkali proteids. In plants, the proteids are generally united with small amounts of organic acids and mineral compounds, particularly phosphorus and potassium. They all respond to certain reactions: (1) Nitric acid gives a permanent yellow color; (2) a solution of mercury and nitric acid, known as Millon's reagent, gives a brick-red color with the acid if heated; (3) a solution of copper sulfate and potassium hydrate gives a violet-colored solution. The proteids, found in living cells, have different properties from those in dead tissue. Proteids readily undergo oxidation, and are chemically altered in the preparation of many foods. When the protein molecule is acted upon by heat, a large number of products are formed, as fatty acids, amides, aromatic bodies, ammonia, and carbohydrate-like bodies. The most common change which the proteids undergo is the rearrangement of the atoms and radicals in the molecule. The coagulation of albumin by heat is a chemical reaction in which the atoms and radicals in the albumin molecule are simply rearranged structurally. The fact that it is possible for such a large class of compounds as the proteids to be composed of only a few common elements, and for the various members to have different properties, is accounted for by differences instructural composition.

Experiment 57.—Testing for nitrogenous organic compounds. Mix 0.5 gram dry clover with enough soda lime to half fill a test-tube. Connect the test-tube with a delivery tube, one end of which leads into another test-tube containing water. Apply heat for from five to seven minutes. Test the distillate with test paper. (Soda lime has the power to decompose proteid material and liberate the N as NH_3. The C and O of the proteid unite and form CO_2 and H_2O.)

Questions. (1) What reaction was obtained when the distillate was tested with litmus? (2) What compound was produced which gave this reaction? (3) What does this indicate that clover contains? (4) Why was this compound liberated?

299. Classification of Proteids. — For purposes of study, the proteids may be divided into five classes: (1) Albumins, (2) globulins, (3) albuminates (casein), (4) peptones and proteoses, and (5) insoluble proteids.

There are some proteids that do not belong to any of the above divisions. The albumin, albuminate (casein), and the insoluble proteids are those found most abundantly in plant and animal bodies.

300. Albumins.—The albumins are proteids soluble in water and easily coagulated by heat. Egg albumin, serum albumin and lactalbumin, are examples of animal albumins. Wheat, oats, rye and nearly all vegetables, when extracted with water, yield some albumin which can be coagulated by heat or precipitation with chemicals. In many vegetables, the albumin is lost when the material is soaked in water for any length of time. Potatoes, for example, lose a large amount of their albumin if soaked in cold water before boiling.

Experiment 58.—Tests for albumin. In each of four separate test-tubes, place a 3 cc. portion of a solution of egg albumin. To No. 1 add 3 cc. strong alcohol. To No. 2, add 2 cc. HNO_3 and heat; when cool, add NH_4OH. To No. 3, apply heat. To No. 4, add a few drops of lead acetate.

Questions. (1) What change occurred when the solution was heated? (2) When alcohol was added? (3) When HNO_3 was used and heat applied? (4) What did the $Pb(C_2H_3O_2)_2$ do? (5) What do these tests show in regard to the properties of albumin.

Experiment 59.—Albumin and allied proteids from oats. Place in a flask 10 grams of ground oats and 50 cc. of water. Cork and shake vigorously; let stand for half an hour or until the next day. Filter (if not clear refilter) and make the following tests with separate portions of the filtrate. (1) To 5 cc. add a few drops of tannic acid. (2) To 5 cc. add a few drops of lead acetate.

Questions. (1) What were the results when tannic acid and lead acetate were added? (2) Do the tests indicate any large amount of albumin? (3) How do these tests compare with those of the preceding experiment?

301. Globulins form a group of proteids insoluble in water, but soluble in dilute salt solution. When animal or vegetable substances, as meat, eggs, wheat, rye or oats, are treated with dilute salt solutions (NaCl), after removal of the albumins, soluble proteid substances called globulins are obtained which are coagulated by heat. There are a large number of vegetable globulins. The chief globulin of meat is myosin. When meat is soaked in a dilute salt solution, and then cooked as food, the myosin is extracted and lost. In strong salt solution, myosin and other globulins are insoluble; hence the use of strong brine in the curing of meats. In the blood, there are globulins present, and in the yolk of an egg, a globulin-like body, vitellin is found. As a rule, globulins do not make up a very large proportion of the proteids of foods.

Experiment 60.—Obtaining globulin from oats. To the residue left in the flask from Experiment 59, add 2 grams of salt and 50 cc. water. Shake vigorously and, after one hour, filter and make the same tests as in Experiment 59. Save the residue in the flask for Experiment 65.

Questions. (1) What results were obtained when the solution was tested with lead acetate and tannic acid? (2) What do these results indicate? (3) What are globulins?

Experiment 61.—Separation of meat globulin or myosin. Test as follows four 3 cc. portions of myosin solution, prepared by soaking fresh meat in a 5 per cent. salt solution. To the first, add a few drops of alum solution. To the second, add a few drops of lead acetate. To the third, add salt until the solution is saturated. To the fourth, apply heat.

Questions. (1) What result was obtained with the alum solution and what does this indicate? (2) What did the lead acetate and the salt solutions do? (3) What was used as the solvent for the myosin? (4) What is myosin? (5) What are the properties of myosin?

302. Albuminates.—The albuminates are a group of proteids widely distributed in both animals and plants. They may be produced by the action of either dilute acids or alkalies upon albumins or globulins. The albuminates are insoluble in water, and when an acid albumin is neutralized with an alkali, the albuminate is precipitated. In like manner, an acid precipitates an alkali albumin. Casein is an albuminate present in milk, and is in a semi-soluble form combined with some of the mineral matter. Casein is soluble in dilute alkalies, but is precipitated by acids. In plants the albuminates are sometimes called vegetable casein. From peas, a casein-like body can be extracted.

Experiment 62.—Separation of meat albuminate or syntonin. To 3 cc. portions of prepared syntonin solution, add: To the first, Na_2CO_3 until neutral, avoiding excess as it dissolves the precipitate; to the second, add NaOH a drop at a time until neutral; to the third, add a few drops of lead acetate. Syntonin solution is prepared by cutting fresh meat into small pieces, and extracting it for four hours, in water containing a few drops of HCl.

Questions. (1) What result was obtained when each reagent was added to the syntonin solution? (2) What was used in the preparation and what as the solvent for syntonin. (3) What is syntonin? (4) What are the properties of syntonin?

Experiment 63.—Preparation of vegetable casein from peas. Place in an evaporator, 1 gram of pea meal, 100 cc. H_2O, and 3 cc. NaOH. Heat on the sand-bath, occasionally stirring. Filter. If the filtration is slow, pour off and use some of the clear solution. Neutralize with HCl and observe.

Questions.—(1) To what class of proteids does vegetable casein belong? (2) What was used as the solvent for extracting the vegetable casein? (3) What effect had HCl? (4) How does vegetable casein resemble that from milk in solubility and other properties?

303. Peptones and Proteoses are closely related groups of proteids present in animal and vegetable bodies. When any proteid material is acted upon by the peptic and tryptic ferments, peptones are formed. These are soluble in water, and are not coagulated by heat or precipitated by acids or alkalies. They are derived from other proteids by ferment action, and are the first products formed when the proteids of the food undergo digestion. In prepared or peptonized foods, the peptonizing process is carried on artificially. When meat undergoes the curing or ripening process, a small amount of peptones is produced. Peptones are naturally present in milk and also in traces in nearly all cereal products. When seeds germinate, proteoses are formed. These compounds are never present in ordinary foods in any appreciable amount.

Experiment 64.—Tests with peptones. Measure into separate test-tubes, three 5 cc. portions of peptone solution. To the first, apply heat and, when cool, add a few drops of tannic acid. To the second, add a few drops of alum solution. To the third, add 5 cc. alcohol. The peptone solution is prepared by treating coagulated egg albumin with pepsin. 5 grams of commercial pepsin are dissolved in 1 liter of water containing 5 drops HCl. This artificial pepsin solution represents the solvent power of gastric juice upon proteid substances. The white of a hard boiled egg is put into a flask, and 250 cc. pepsin solution added ; the flask is then placed in a water-bath which is kept at a temperature of 38° C. for four or five hours.

Questions. (1) What action did the pepsin have on the egg albumin and what was produced? (2) What was the result when heat was applied in test No. 1, and how does this compare with the result when egg albumin was similarly treated? (3) What effect did tannic acid and alum have upon the pepsin solution and what did they produce? (4) What was the result when alcohol was added? (5) What are peptones? (6) What does this experiment show in regard to some of the properties of peptones?

304. Insoluble Proteids.—The insoluble proteids are present in plant and animal bodies in larger amounts than are any of the other proteids, and include a large number of similar though chemically distinct bodies. Muscular tissue is composed largely of insoluble proteids. In seeds, the term gluten is frequently applied to this class of compounds which is a mixture of two or more insoluble proteids. Wheat gluten for example is composed of gliadin and glutenin. Gliadin is a glue-like body which binds together the flour particles, and in bread-making, enables the gas to be retained in the dough. Glutenin is a fine, gray material which unites mechanically with the gliadin to form gluten. An excess of gliadin produces a soft gluten.

As a class, the insoluble proteids are not soluble in water or dilute salt solutions, but are soluble in dilute acids and alkalies. They all undergo the peptonizing process and yield proteoses and peptones. The insoluble proteids are the most common form of proteids in foods.

Experiment 65.—Obtaining insoluble proteids from oats. To the residue left in the flask from Experiment 60, add 2 cc. NaOH and 50 cc. water. After shaking and allowing half an hour (or until the next day) for the extraction of the proteids, filter off the solution and make the following tests: (1) Neutralize 5 cc. with HCl, and if no precipitate appears, add a few drops of lead acetate; (2) neutralize 5 cc. with HCl and evaporate to dryness on the water-bath.

Questions. (1) Why was NaOH used? (2) What effect did the HCl and lead acetate have when added to the solution, and what was formed? (3) How did this precipitate of insoluble proteids from oats compare in amount with the globulin and albumin precipitation in Experiments 59 and 60? (4) What is an insoluble proteid?

305. Food Value of Proteids.—The proteid compounds of plant and animal bodies serve three purposes as nutrients: (1) To produce new muscular tissue and vital fluids in the body, and supply material for repairing broken-down tissue; (2) to produce heat and energy; (3) to assist in the production of fat.

The main function of the proteids is to produce new proteid tissue in the body, and to furnish a material for the repair of old or worn-out proteid matter. The vital fluids of the body, as blood, chyme, milk, and the digestive fluids, all contain proteids, and the animal body is incapable of producing any from either non-nitrogenous or amide compounds. When the food fails to supply a sufficient amount of protein, the body uses its reserve supply as long as it lasts, and then starvation results. When there is an excess of proteids in the food, it is used for producing heat or is stored up in the body as fat. Either an excessive or a scant amount of proteids in a human or animal ration is not desirable or economical. As stated under chemical properties of proteids, Section 298, the proteid molecule, when broken up, forms a large number of simpler bodies, as fatty acids and carbohydrate radicals; hence, it is poor economy to feed proteids in excess and have part perform the functions of fats and carbohydrates. Protein is present in many foods in deficient amounts, and when such foods are used, they should be combined with those rich in proteids. There are a few proteids which are poisonous bodies. Some of the toxins produced during disease are proteids.

306. **The Amount of Proteids in Plants** varies according to the kind, stage of growth, and part of the plant considered. Seeds always contain the largest amount, while roots and stalks contain the least. In wheat, oats, barley and rye, the amount ranges from 10 to 15 per cent., while in corn, it ranges from 9 to 12 per cent. Beans and peas contain about 25 per cent. Clover hay contains from 11 to 14 per cent.; timothy hay and corn fodder, 6 to 9 per cent.; while in straw there is usually less than 4 per cent. During the early stages of growth, the dry matter in all plants is relatively richer in proteids than at maturity. This is because the proteids are formed mainly in the early stages, while the carbohydrates are produced more abundantly in the later stages of growth.

307. **Crude Protein.**—This term is applied to the nitrogenous compounds of foods, taken collectively, as a group. The word *crude* is used to distinguish this group because

it contains various nitrogenous bodies, not proteids. Pure protein is a simple chemical compound, while crude protein consists of a group of compounds of which pure protein is one. The albumin of eggs and milk and the gluten of grains are types of pure proteids. In many foods, as potatoes, roots, and fruits, less than half of the crude protein is pure protein. Crude protein, from different sources, is unlike in character, composition, and, to a certain extent, in food value. Less is known of its composition and food value than of any other class of nutrients in foods.

In the analysis of plant and animal substances, the chemist first determines the per cent. of total organic nitrogen and then multiplies this by 6.25 to obtain the equivalent amount of crude protein. This is because the proteids contain, on the average, about 16 per cent. nitrogen, or there is about one part of nitrogen to every 6.25 of protein ($100 \div 16 = 6.25$). The nitrogen can be determined with accuracy; in fact, the method for its determination is one of the most accurate in chemistry. In brief, the method consists in first digesting a small weighed amount of material in a flask

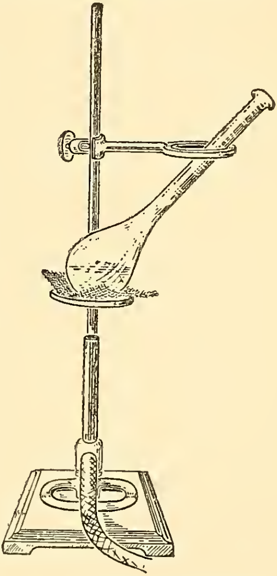


Fig. 81.—Digestion apparatus used in the determination of nitrogen.

with sulfuric acid to oxidize the organic matter and convert the nitrogen into ammonium sulfate (see Fig. 81).

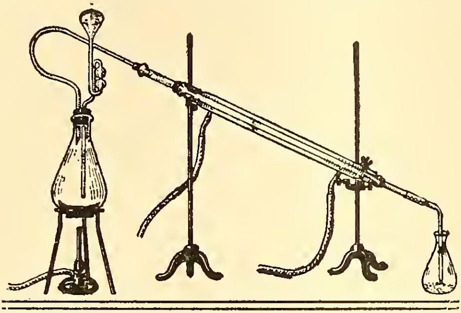


Fig. 82.—Distillation apparatus used in the determination of nitrogen.

The nitrogen, in the form of ammonium sulfate, is then liberated as free ammonia, distilled and its amount determined (see Fig. 82).

Albuminoids

308. Composition of Albuminoids.—This term is applied to a class of bodies resembling proteids, but differing from them in composition and food value. Albuminoids are found in both animal and plant bodies, but more abundantly in animal tissues. Some albuminoids are composed of carbon, hydrogen, nitrogen, and oxygen, while others contain, in addition, phosphorus, sulfur and other elements.

309. Nuclein is an albuminoid found in both plant and animal bodies; it is the material of which the nuclei of cells are composed, and has been separated from milk, the yolk of egg, and white blood corpuscles, as well as from plant substances. This albuminoid contains phosphorus, and has been assigned the formula $C_{20}H_{49}N_9P_3O_{22}$. Nuclein takes an important part in the growth and life processes of both plant and animal cells. From different sources it has slightly different chemical properties. It is probably a mixture of several bodies, and not a distinct chemical compound.

310. **Gelatin** is an albuminoid obtained from connective tissue and bones by the action of either boiling water or dilute acids upon an albuminoid called collagen. Commercial gelatin or glue is the crude product obtained from animal refuse. The formula $C_{102}H_{151}N_{32}O_{39}$ has been assigned to gelatin. Gelatin contains no sulfur, and has a different proportion of nitrogen from that found in proteid bodies.

311. **Mucin** is an albuminoid present in connective tissue. It is the chief constituent of mucus, and imparts sliminess to the secretions of the mucous membrane. Mucin is present in the saliva from the submaxillary glands, and in the bile and other fluids of the body, particularly those of an alkaline nature.

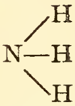
312. **Elastin** is an insoluble albumoid found in connective tissue. Keratin is the hard, horny material found in nails, hoofs and horns, while chondrin is obtained from cartilage. A number of other albuminoids also are present in both animal and plant bodies.

313. **Food Value of Albuminoids.** — Gelatin and most of the animal albuminoids undergo digestion, but cannot take the place of protein in a ration. An animal

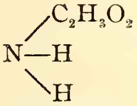
would soon die if its nitrogenous food were entirely in the form of gelatin. Gelatin, when combined with other nutrients, may, however, prevent the rapid conversion of the tissue proteids into circulatory proteids, and thus aids in establishing a proteid equilibrium in the body. Nuclein and some of the nucleated albuminoids have a higher food value than gelatin, and are considered as having the same value as the true proteids. As a nutrient, the gelatin albuminoids conserve the proteids of the body, but do not take the place of proteids in the repair of worn-out tissues.

Amides and Amines

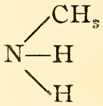
314. Composition and Properties.—The amides and amines are heterogeneous compounds found in both animal and plant bodies. They are less complex in composition than either the proteids or albuminoids, and are produced by replacing one or more of the hydrogen atoms of ammonia with an organic radical. If the radical is acid in character, an amide is formed; if alcoholic or basic, an amine is produced. Amides and amines are related to ammonia as will be observed from the following formulas:



Ammonia.



Amide.
(Amidoacetic acid.)



Amine.
(Methylamine.)

When the methyl group or radical replaces one of the hydrogen atoms of NH_3, the product is methylamine. When the acetic acid radical replaces one of the hydrogen atoms of NH_3, the product is amidoacetic acid. The amides and amines are sometimes called compound ammonias, and are produced in plants from ammonia during growth, and in animals during the digestion of proteids.

315. Formation and Occurrence in Plants.—The amide and amine compounds in plants are present mainly in the early stages of growth. The young plant takes up from the soil simple nitrogenous compounds, as ammonia, then a chemical change occurs in the tissues of the plant, and as a result, a part or all of the hydrogen of the ammonia is replaced, and an amide is formed. In the study of the composition of proteids (see Section 295) it was stated that the proteid molecule when decomposed yields amide and amine products; consequently it would appear that these compounds are intermediate products in the production of proteids. In the early stages of plant growth, amides are present in greatest abundance, but as the plant approaches maturity, they are used for the production of proteids. In clover, for example, 35 per cent. of the total nitrogen is in the form of amides before bloom, while only 12 per cent. is in the same form after bloom.

316. Formation and Occurrence of Amides in Animals.—In the animal body, amides and amines are not formed from ammonium compounds, as in plants, but from proteids. When the proteid molecule is broken up, as in digestion, amides and amines are produced. Urea, an amide, is one of the final products in the digestion of protein, and is excreted from the body in the liquid excrements, while amidoacetic acid is excreted with the solid excrements. The animal body cannot produce proteids from amides, or amides from ammonia. This elaboration or construction process can take place only in the plant. The animal body can simply make over into other forms, the proteids supplied in the food, or decompose them and form amides and other products.

In animal tissues, many amides are produced during fermentation and decay, as methylamine, the base which gives the characteristic odor of fish. Methylamine is also found in rye fodder when the plant is at the heading-out stage, and imparts a fishy taste to the milk of cows fed upon such fodder. In meats, these compounds are associated with other bodies, as ptomaines, which are of a poisonous nature. Amides are also produced during the digestion of food, and if the intermediate products between proteids and amides are not completely oxidized, poisonous substances are formed.

317. Food Value of Amides.—The amides do not have a high food value compared with the proteids, and cannot replace proteids in a ration. The amides possess only a secondary food value, and, like the gelatin albuminoids, may to a limited extent prevent a rapid waste of body tissue. Some give taste and character to foods, as asparagin in asparagus, and in meats they are the bodies which give flavor. Some of the amides have medicinal properties, while others are poisonous.

318. Amount of Amides in Foods. — In matured grains, less than 5 per cent. of the total nitrogenous matter is in the form of amides, and in meats there is less than 1 per cent. In some foods, notably roots and tubers, the amides constitute a third or more of the nitrogenous matter. In fodders, the amount depends upon the stage of growth at which the crop is cut. When mature, from 10 to 15 per cent. of the nitrogenous matter is in the form of amides, while in the early stages of growth, there are two or three times as much. The amides and amines form a part of crude protein (see Section 307). In comparing the crude protein content of food, the amount of amide nitrogen should be considered, because the amides are of less food value than the proteids.

319. Protein Production and Disintegration.—The following cycle of changes takes place in the production of proteids in plants:

(1) Ammonia is taken from the soil.
(2) An amide is produced from ammonia.
(3) A proteid is finally formed from the amide.

When plants are used as food, the reverse order of changes takes place in the animal body:

(1) The proteid of the food undergoes digestion, and is made over into proteid tissue in the body. This proteid tissue is finally broken up into amides.

(2) The amide is expelled from the body as waste matter.

(3) In the soil, the amides are changed to ammonia, and are then ready to begin anew this cycle of changes.

Alkaloids

320. General Composition.—The alkaloids are nitrogenous organic compounds present in many animal and plant bodies, but not found in any appreciable amount in food plants. They are basic in character and unite with acids to form salts, just as ammonia unites with acids to form salts. Quinin, for example, in an alkaloid, and with sulfuric acid yields quinin sulfate. Animal alkaloids are sometimes called ptomaines and leucomaines. The vegetable alkaloids are generally named from the species of plant or source from which they are obtained, as Peruvian bark alkaloids, lupine alkaloids, and opium alkaloids.

321. Plant Alkaloids.—No alkaloids are found in cereals or ordinary food plants, though at one time it was supposed that oats contained such a stimulating body to which the name avenin was given; later investigations have shown that there is no avenin or alkaloidal body in oats. The alkaloids chemically are closely related to the amines, and are produced by the action of amido compounds upon other bodies. They are also produced by the action of fungus bodies, as eargotin, the alkaloid from eargot or grain smut. While found most abundantly in the leaves and seeds, they are found in all parts of plants. Some are cultivated for these bodies which possess medicinal properties. Many poisonous weeds contain alkaloids as the water hemlock and monk's hood. Large numbers of alkaloids are known, and since they possess medicinal rather than food value, they are of more importance to the medical and pharmaceutical than to the agricultural student. A few of the more common alkaloids and their sources are :

Piperine, from seeds of black pepper.

Sinapore, from seeds of mustard.
Vicine, from seeds of vetch.
Nicotin, from leaves of tobacco.
Quinin, from peruvian bark.
Strychnin, from strychnos bean.
Brucine, from strychnos bean.
Morphin, from opium (seeds of poppy).
Lupinin, from lupin seeds.

322. **Animal Alkaloids.**—In the animal body alkaloids are produced by ferment action. During disease, and when the proteids of the food fail to undergo the natural chemical changes of digestion, alkaloids, or ptomaines, are produced which are active poisons or toxic bodies. When animal tissue undergoes decay, ptomaines are produced as the result of ferment action. In stale meat, fish, and cheese, there are a number of such bodies.

323. **Food Value and Production.** — The alkaloids cannot be regarded as nutrients as they possess no direct food value. Medicinally, many are valuable because of their action upon certain nerve centers. Some alkaloids lessen the value of foods because they prevent the normal process of digestion. A few alkaloids have been produced in the laboratory by synthetic methods, and it is believed that in a short time all of the more important ones will be produced in this way.

324. **Mixed Nitrogenous Compounds.**—There are a few nitrogenous organic compounds present in foods which do not belong to any of the four divisions: Proteids, albuminoids, amides, and alkaloids. Such bodies are called

mixed nitrogenous compounds, and are closely related to both the nitrogenous and non-nitrogenous groups.

325. Lecithin is a nitrogenous fat. It is soluble in ether, and has many of the characteristics of fats. It contains fatty acids in combination with nitrogenous bases and other bodies. It is present in milk, egg-yolk, and in small amounts in all of the cereals.

326. Nitrogenous Glucosides.—There are a number of glucosides which contain nitrogenous radicals. These glucosides, when treated with acids, yield glucose and nitrogenous acid products. The nitrogenous glucosides and lecithin may be regarded as compounds which are intermediate in the classification of the organic compounds into nitrogenous and non-nitrogenous groups.

327. General Relationship of the Nitrogenous Organic Compounds.—A general relationship exists among the nitrogenous compounds similar to that among the non-nitrogenous (see Section 289). The amides and amines are the simplest in chemical structure of the nitrogenous compounds, while the proteids are the most complex. In plants, the amides are intermediate compounds formed in the production of proteids. The proteid molecule contains, with other bodies, amide and fatty acid radicals. Amide products are also obtained from the albuminoids. Thus it appears that the amides and amines form the basal structure of the nitrogenous part of the molecules of proteids, albuminoids, and alkaloids, and these compounds differ from each other chemically, according to the nature and kind of radicals in combination with the different amide and amine compounds.

CHAPTER XXV

Chemistry of Plant Growth

328. Seeds.—A seed is an embryo plant surrounded by reserve food materials in the form of mineral matter and nitrogenous and non-nitrogenous compounds.

329. Ash of Seeds.—The proportion of ash in seeds is small compared with that in other parts of plants. For example, the wheat kernel contains 2 per cent. and the straw 7 per cent.; corn contains 1.75 per cent. and the stalks 7 per cent. While seeds contain comparatively little ash, this ash is more concentrated in the essential elements than that of the other parts of plants. In the seeds are stored large amounts of phosphorus pentoxid, magnesia and potash (ash elements which are of most importance for the nutrition of the young plant), while in the straw are found the largest amounts of the non-essential mineral elements, as silicon, sodium and chlorin. The per cent. of the various ash elements in cereals and other seeds is given in Section 209. The amount of ash in seeds is quite constant, more so than in the stems, leaves or other parts of plants. In mature wheat, there is rarely more than 2.10 per cent. or less than 1.80 per cent., while in the straw, the amount may range from 5 to 9 per cent. Constancy of composition is a characteristic of the ash of seeds.

330. Non-Nitrogenous Compounds of Seeds.—Starch, cellulose, and fat are usually the most abundant non-nitrogenous compounds in seeds. Small amounts of other non-nitrogenous bodies, as sugar, gums, pentosans and organic acids, are also present. There is no regular law as to the way in which the reserve food is stored up in seeds. Even in the same family of plants, the nature of this reserve food may vary between wide limits. Starch forms the largest proportion of the reserve food of the cereals. In oil seeds, as flax, rape and mustard, fat is the main form of non-nitrogenous food. Since fat is about 2.25 times more concentrated in fuel value than starch, it follows that in oil seeds, a large amount of reserve material is stored up in a small space. Oil seeds are, as a rule, small in size, but concentrated in both non-nitrogenous and nitrogenous food. The cellular tissue of seeds is composed of cellulose and pentosan materials. The amount of pure cellulose is generally small.

331. Nitrogenous Compounds of Seeds.—The nitrogenous compounds of seeds are present mainly in the form of insoluble proteids, as the glutens of the cereals. Small amounts of other proteids, as albumin, globulin and proteose, are also present, as well as some of the albuminoids, as nuclein, and a small amount of amide compounds. In studying the carbohydrates, it was found that starch was present in regular organized forms called starch granules. In many seeds, particularly cereals, the proteids also are present in organized forms called aleurone grains. Under the microscope, the aleurone grains look like crystals. They are not true crystals because they are not built on a definite plan. An aleurone grain consists mostly of proteid matter enclosed in a nitrogenous envelope. The nitrogenous compounds of seeds are stored up mainly in the germ or portion adjacent to the embryo. The amount of nitrogenous material in seeds is, like the ash, quite constant in form and amount.

332. Chemical Changes during Germination.—All of the food materials in seeds undergo chemical changes during the process of germination. The chief agents in bringing about these changes are the various kinds of soluble ferments which are always present in seeds. The more important changes can be summarized as follows : Cellulose is changed to soluble carbohydrates; starch is changed to soluble forms and then into dextrose bodies ; fat is changed to starch ; insoluble proteids are changed to proteoses and a small amount to amides. Organic acids are produced from both nitrogenous and non-nitrogenous compounds during germination.

333. Change of Starch to Soluble Forms.—When seeds germinate, the starch is changed to soluble forms before it is utilized by the plantlet. During conversion of starch into soluble forms, the diastase ferment becomes active, rendering the granulose soluble, and finally leaving nothing but a pitted cellulose skeleton which is also rendered soluble. The change of starch into soluble forms and dextrose bodies is brought about by the action of ferments, particularly diastase which is found in all seeds. During the process of germination, some of the starch is oxidized, and heat is produced. Not only starch, but other carbohydrates, as pentose and cellulose, likewise undergo similar change during germination.

Experiment 66.—Reaction of germinating seeds. Fill a cylin-

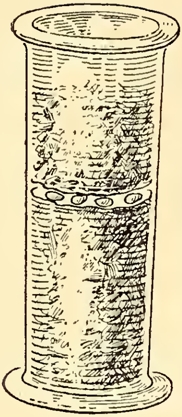


Fig. 83.

der with moist sawdust; then place upon the sawdust between two blue litmus papers a few wheat seeds. Cover with a little of the moist sawdust. After germination, examine the litmus paper.

Questions. (1) What was the reaction of the rootlets upon the litmus paper? (2) How was the material which caused the reaction produced? (3) What does this suggest as to the solvent action of plant roots? (4) How would the dry matter of the germinated seeds compare with that of the original seeds?

334. Change of Fats to Starch.—In germination, the fats are first broken up into fatty acids and then converted into starch, soluble carbohydrates as dextrin and invert sugars. It is estimated that 887 parts of fat will produce 1700 parts of starch by the simple addition of oxygen from the air. Ferment action causes this change to take place. In the oil seeds, about twice the amount of reserve food is stored in the same space in the form of fat as in other seeds in the form of starch.

335. Change of Insoluble Proteids to Soluble Forms.—The proteid compounds of seeds, present mainly in insoluble forms, are converted by ferment action into soluble forms as proteoses. Some of the soluble proteids are broken down into amides which are then in condition to be transported through the plant tissues and used as building material. After passing through the cell walls, these compounds are reconstructed into proteids.

There is always a slight loss of nitrogen in the germination of seeds.

336. Germination of Seeds and Digestion of Food Compared.—The chemical changes which take place in the germination of seeds are similar to those which take place in the digestion of food. In the germination process, starch, fat, and proteids are changed by ferment action to soluble forms. The diastase and peptonizing ferments are among the most active in producing the chemical changes in both the germination and digestion processes. Seed germination is, in part, a digestion process.

337. The Necessary Conditions for Germination are: (1) Moisture, (2) heat, and (3) oxygen. The same conditions which produce decay are necessary for germination. The temperature required for germination ranges between comparatively narrow limits:

Wheat	35° F. to 104° F.
Barley	38° F. to 104° F.
Peas	44.5° F. to 102° F.
Corn	48° F. to 115° F.

The necessity of oxygen for germination is shown by the following experiment: When seeds are put into water those that float are generally the only ones that germinate. A few of those that sink may germinate, getting their oxygen from that dissolved in water. If a current of air is passed through the water all of the seeds will germinate. Oxygen is necessary during germination in order to oxidize some of the reserve material and produce heat. Seeds, in germinating, always lose weight.

Malted or germinated seeds weigh less than the original seeds.

338. Heavy- and Light-Weight Seeds.—While seeds are quite constant in chemical composition, there is, however, a slightly greater amount of total plant food in heavy- than in light-weight seeds. In the case of wheat, experiments have shown that the additonal reserve food in heavy-weight seeds favorably influences the growth of the crop, particularly when the soil is slightly deficient in available plant food. The additional reserve food in heavy-weight seeds enables the young plant to reach a higher stage of growth before being compelled to collect and assimilate food from the soil. When the soil is in a high state of fertility the difference in results between light- and heavy-weight seeds is less noticeable.

Experiment 67.—Calculation of plant food in seeds. Weigh 100 plump, well-formed wheat kernels. Then from this weight and the following data compute the grams of nitrogen, phosphoric acid and potash per 1,000 wheat kernels. Wheat contains about 2 per cent. nitrogen, and 90 per cent. dry matter. The dry matter contains about 2 per cent. ash, approximately 50 per cent. of the ash being P_2O_5, and 33 per cent. K_2O. Repeat the experiment, using 100 shrunken wheat kernels. Tabulate and compare the results.

Questions.—(1) How much more reserve plant food is there as N, P_2O_5 and K_2O in heavy- than in light-weight seeds?

Movement of Plant Juices

339. Joint Action of Chemical and Physical Agents.—The compounds produced in the leaves of plants are transported and stored in other parts, as the seeds or roots; this is brought about by the joint action of physical and chemical agents. This action can best be understood by first considering a few of the properties of plant tissues, as porosity, capillarity, and osmosis.

340. **Porosity of Tissues** is a property common to all forms of matter, and one possessed particularly by vegetable substances. The living plant not only admits the passage of water through its tissues, but absorbs it until the pores are filled. Animal and vegetable tissues always possess the power to take up and tenaciously hold water within their fibers. This is, in part, due to capillary action (see Section 20, Chemistry of Soils and Fertilizers). Capillarity, assisted by evaporation, explains only in part the movement of the plant juices. Compounds formed within the leaf must be transported in an opposite direction to that taken by the sap in moving from the roots to the leaves. This movement is effected by osmosis, and chemical reaction within the cells.

341. **Osmosis.**—When a bottle filled with a solution of salt, colored with litmus, is placed in a large vessel of water, the bottle will discharge its contents into the water and the movement of the solutions can be followed with the eye. If sugar and salt solutions are separated by a membrane, there is a gradual interchange between the two solutions. Some of the sugar finds its way into the salt solution, and some of the salt finds its way into the sugar solution. This action or interchange is still further increased when the solutions are of different densities and when chemical action is taking place on both sides of the membrane. Such an action takes place in plant tissues, which are composed of a large number

of small cells, the walls of which serve in part, as membranes, and offer but little resistance to diffusion. The cells are filled with sap, which is acid in nature and contains numerous solid substances in solution. Between the cells are intercellular spaces filled with sap of different density from that within the cells and charged with numerous alkaline matters taken from the soil. Here, then, are nearly the same conditions as when the salt and sugar were separated, and the result, osmosis, is the same in each case. Within the cell walls active chemical changes are taking place which aid in this interchange. It cannot be said that there is a constant flow of sap in any one direction, as blood flows in the animal body. It was formerly believed that there were two courses of sap in the plant, upward and downward. The movement of the plant juices is now considered as due to (1) capillary action, aided by evaporation which disturbs the equilibrium of the plant juices, together with (2) osmosis aided by chemical action within the cells. These factors are, to a certain extent, mutually dependent upon each other. By their joint action, aided by the chemical changes within the plant, the water from the soil is taken into the plant through the roots with the mineral matter in solution, which serves as food, and finds its way all through the plant, finally returning to the roots charged with the material that can be made only in the leaf and by the aid of light and sunshine.

Chlorophyl and Protoplasm

342. Chemical Action in Leaves of Plants.—All of the organic compounds of plants are produced within the cells of the leaves. The mineral food and nitrogen taken from the soil and the carbon dioxid from the air are chemically united in the cells of the leaves to form the various non-nitrogenous and nitrogenous compounds of plants. Chlorophyl and protoplasm are the two substances which take the most active part in the production of the organic matter.

343. **Chlorophyl** is the name applied to the material which imparts the green color to plants. It is not a simple compound, but is composed of a number of closely related organic compounds. The chlorophyl body contains both organic and mineral matter. Chlorophyllan is one of the compounds obtained from chlorophyl. Iron, phosphorus and magnesium are among the more important mineral elements necessary for the functional activity of the chlorophyl body. This mineral matter is combined with the organic compounds which form a part of the chlorophyl grain. Chlorophyl is contained in the active living cells of plants, but makes up only a small part of the contents of the cell.

344. **Protoplasm.**—The chlorophyl body is suspended in a gelatinous, colorless liquid called protoplasm which is composed mostly of proteid and albuminoid materials. It is the living substance of the plant organism, and is the part which gives life and activity. In chemical composition, it is exceedingly complex, and is composed of a number of proteids, albuminoids and other organic compounds. The protoplasm, aided by the chlorophyl, has the power of combining the food elements and producing

all of the organic compounds of the plant. Protoplasm is the living part of both plant and animal cells.

345. **Production of Chlorophyl.**—When the plant cell is first formed, the protoplasm contains no green grains. Small, colorless grains first appear, and then the greening of these grains takes place. The chlorophyl body may make its appearance in the absence of light, but the last stage of its development can take place only under the influence of light and at a higher temperature than is required for the first stage of the process. With a cool temperature, there is plant growth, but the vegetation looks yellow because there is not sufficient heat for the completion of the second part of the process of chlorophyl development. Chlorophyl is destroyed by intense light as well as by the absence of light. It is soluble in ether and alcohol and is one of the constituents of ether extract. The green color is easily destroyed, but the chlorophyl body is quite stable and resists the action of dilute acids and alkalies. Chlorophyl loses its activity, and undergoes a decided change in composition as the plant matures. Some of the elements which compose the chlorophyl, as nitrogen and phosphorus, are used for seed formation. At the time of the greatest amount of color in plants, there is the greatest cell activity and the largest amount of plant tissue is being produced. When a plant ripens, the decline of activity of the cells can be observed by the change in the color of the plant. When corn, for example, ripens, the lower joints of the stalk turn yellow first, indicating that growth and activity have ceased in those parts. Then

the upper leaves become yellow, and finally the husk becomes yellow and inactive. Chlorophyl is one of the principal agents which takes an active part in plant growth, and whenever chlorophyl is destroyed, plant growth is checked.

Experiment 68.—Extracting chlorophyl from leaves. Place in a test-tube, 0.5 gram of dry, green leaves. Add 10 cc. alcohol, shake vigorously and, after the alcohol is colored green, filter off the solution, and evaporate to dryness at a low temperature on the water-bath.

Questions.—(1) Describe the appearance of the chlorophyl residue. (2) What is chlorophyl? (3) Of what is it composed? (4) What other solvents could be used in place of alcohol.

346. Function of Chlorophyl.—The chief function of chlorophyl, aided by protoplasm, is the production of starch and other organic compounds in the cells of plant leaves. Chlorophyl alone cannot perform this function, but must be associated with, and aided by, protoplasm. Minute starch grains are sometimes found within the chlorophyl grains. The actual growth of starch within the chlorophyl body can be observed with the microscope. No other compounds have been found so organically connected with the chlorophyl grains as starch. If a plant is placed in darkness, both the starch and the coloring-matter in the plant cells disappear. The plant cell is the chemical laboratory in which the various organic compounds, as starch, sugar and proteids, are elaborated. From the cells in the leaves, they are transported to other parts of the plant as the seeds, roots or tubers, where they are stored up and serve as reserve food.

347. Production of Organic Matter.—By the joint action of the protoplasm and chlorophyl within the plant cells, starch and all other organic compounds are produced from the carbon dioxid of the air and from the water, mineral matter, and nitrogen of the soil. All of the carbohydrates can be produced from starch as was stated in Section 289, which discusses the general relationship existing between the various non-nitrogenous compounds. Fat, as well as other non-nitrogenous compounds, is produced from starch. Proteids are produced from amides. By a succession of chemical changes, the amide molecule takes on fatty acid and carbohydrate radicals, and as a result, complex proteids are produced. All of these chemical changes take place within the plant cell; and, for the production of the various compounds which constitute the dry matter of plants, the essential mineral elements, nitrogen in combination, carbon dioxid and water, are required.

CHAPTER XXVI

Composition of Plants at Different Stages of Growth

348. Composition and Stage of Growth.—Plants do not have the same chemical composition at different stages of growth. The chlorophyl and protoplasm are most active in the early stages and produce the nitrogenous compounds more rapidly than the non-nitrogenous ones. The later stages of growth are utilized mainly for the production of carbohydrates and for the various chemical and physical changes incident to ripening and the transfer of the organic compounds from the leaves to the seeds. Plants have a different food value at their different stages of growth as well as a different chemical composition.

349. Assimilation of Mineral Food by the Wheat Plant.—The various elements of plant food utilized by spring wheat are assimilated quite rapidly in the early stages of growth. The mineral matter being essential for the production of the organic compounds is taken from the soil in advance of their formation. Before the crop has completed the first half of its growth, over 75 per cent. of the total mineral matter has been taken from the soil. Of the mineral elements, phosphoric acid, potash and lime are assimilated most rapidly.

350. Assimilation of Nitrogen by the Wheat Plant.—The nitrogen utilized by the spring wheat crop is taken from the soil in advance of the mineral matter.

Nitrogen is assimilated by the plant more rapidly than any of the elements which form a part of the organic compounds. When the plant has completed half its growth, under normal conditions about 85 per cent. of the total nitrogen required by the crop has been taken from the soil. This is one reason why nitrogen and the essential ash elements should be present in the soil in available and liberal amounts for a wheat crop. When the largest amount of any element or compound is taken as 100, the corresponding amounts present during the different stages of growth of the wheat plant are as follows:

	Wheat, 50 days, before heading out.	Wheat, 65 days, headed out.	Wheat, 80 days, milk state.	Wheat, harvest time.
Total dry matter........	46	59	95	100
Organic matter.........	44	57	90	100
Total nitrogen..........	86	89	96	100
Potassium oxid.........	45	88	100	94
Calcium oxid...........	67	91	100	96
Magnesium oxid........	57	68	99	100
Phosphoric anhydrid....	80	83	98	100

351. Clover; Rapidity of Growth.—In clover, the same general order of changes occurs at the different stages of growth as in wheat, but as the two plants are so unlike, clover being a biennial and a legume, and wheat an annual and a grain, the rapidity of growth and formation of organic compounds in the two plants are naturally dissimilar. The largest amount of the dry matter in clover is produced between early and full bloom. During this period about 60 per cent. of the organic compounds are formed. As in the case of wheat, the nitrogenous

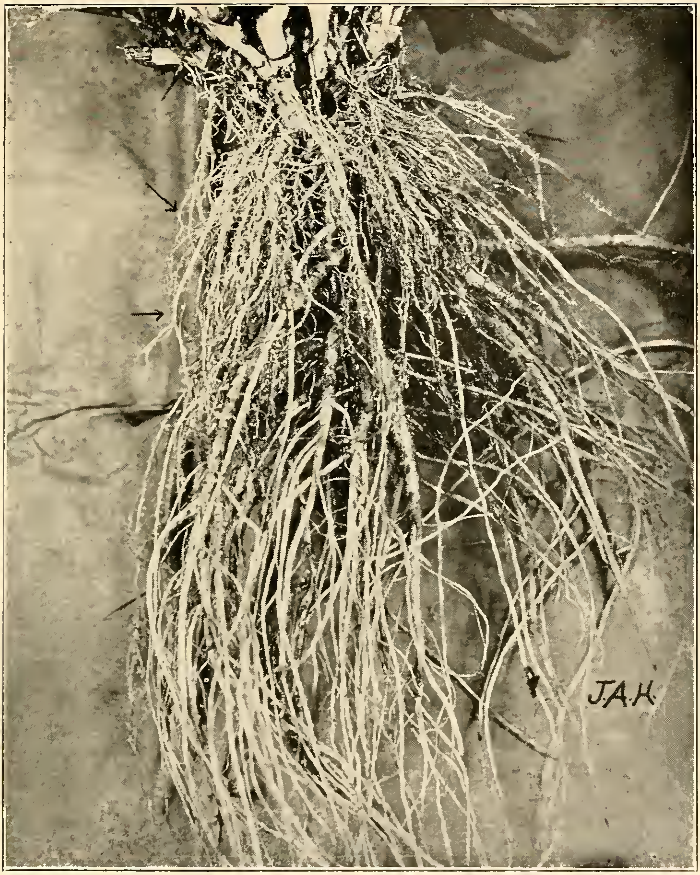


PLATE III.—Clover roots.

compounds are formed more rapidly and in advance of the non-nitrogenous ones. At the time of early bloom, about 37 per cent. of the total nitrogenous compounds have been formed, but the crop at this stage of development has only 31 per cent. of the total organic compounds produced during growth. When clover is very young, before the flower head is visible, only about 10 per cent. of the organic compounds have been produced, but this organic matter is rich in nitrogenous compounds as it contains about 15 per cent. of the total amount assimilated by the crop; a large share of this nitrogen, however, is in the form of amide compounds. The composition of the leaves and stems, at the different stages of growth, show that, at first, the leaves contain about 2.5 times as much nitrogenous matter as the stems, while at maturity, there is less than twice as much. At the time of full bloom, the largest amount of nitrogenous matter is present, and it is then in the form of proteids to the extent of about 88 per cent. In the last stages of growth, there is also a notable increase in the content of crude fiber. The differences in composition and feeding value between clover, cut and cured in full bloom, and at maturity are as follows:

Clover at full bloom.

1. The crop contains less fiber than when mature.
2. The crop contains its maximum amount of proteids.
3. A smaller yield per acre is secured than at maturity, but the crop is more concentrated in protein.
4. The nutrients in the crop are more evenly distributed.
5. The crop contains its maximum amount of essential oils, which impart palatability.
6. The nutrients in the clover are more digestible.

Clover when ripe.

1. The crop contains a larger amount of fiber.
2. The crop contains a smaller per cent. of protein than when in full bloom.
3. A larger yield per acre is secured, and the crop is more concentrated in carbohydrates.
4. Some of the nutrients in the crop are transferred to the seeds, leaving less in the stems.
5. At maturity, there are less of the essential oils than at any other period.
6. At maturity, the crop is less digestible than at full bloom.

COMPOSITION OF CLOVER AT DIFFERENT STAGES OF GROWTH.

	Flower head invisible. Per cent.	Early bloom. Per cent.	Full bloom. Per cent.	End of flowering. Per cent.	Ripe. Per cent.
Water	86.00	85.59	74.96	71.65	33.47
Dry matter......	14.00	14.41	25.04	28.35	66.53

COMPOSITION OF THE DRY MATTER.

Ash............	10.57	10.22	6.85	7.02	6.21
Ether extract....	5.35	4.70	5.73	4.26	3.92
Crude protein ...	23.61	17.19	14.81	14.40	14.06
" fiber......	13.37	20.08	24.62	25.28	26.60
Nitrogen-free extract..........	47.10	47.81	47.99	49.04	49.21

COMPOSITION OF THE DRY MATTER OF THE LEAVES AND STEMS.

	Flower head invisible.		Early bloom.		Third period.	
	Leaves. Per cent.	Stems. Per cent.	Leaves. Per cent.	Stems. Per cent.	Leaves. Per cent.	Stems. Per cent.
Ash	10.02	11.02	10.07	11.30	9.19	4.87
Crude protein	30.68	13.44	27.38	11.25	19.37	11.26
" fiber ...	10.48	18.46	10.51	26.32	15.36	35.27

When the largest amount of any compound in the crop is taken as 100, the percentage amounts at the different periods of growth are as follows:

	Flower head invisible. Per cent.	Early bloom. Per cent.	Full bloom. Per cent.	End of flowering. Per cent.	Ripe. Per cent.
Dry matter	9	31	97	100	97
Total ash	14	46	98	100	95
Total nitrogen	15	37	100	96	94
Proteid nitrogen	67	70	88	85	83
Fiber	5	24	92	96	100
Potassium oxid	15	50	100	94	86
Calcium oxid	15	37	97	100	97
Magnesium oxid	8	35	100	92	91
Phosphoric anhydrid	14	34	98	100	98

(These tables are from Minn. Expt. Sta. Bull. 34.)

352. Flax; Rapidity of Growth.—The flax plant has a short growing period, about seventy days, and the plant food is assimilated at a rapid rate. Before the time of bloom, the nitrogenous material and mineral matters have been absorbed in quite large amounts. When 40 per cent. of the nitrogenous matter has been produced, the flax plant contains 55 and 60 per cent., respectively, of its total nitrogen and mineral matter. At the time the flax is in full bloom, 75 per cent. of the organic compounds have been formed. After seed formation begins, there is no nitrogen or mineral matter taken from the soil. Flax is very rich in nitrogen, containing even more than clover. This is one of the few crops in which the ash in the seed exceeds that in the straw; the seed contains about 3.75 per cent. ash, while the straw contains less than 3 per cent. The oil in the seed is produced mainly from starch in the later stages of growth. Between full bloom and maturity, less than 25 per cent. organic matter is produced. The rate of formation of the organic matter and assimilation of the elements from the soil are given in the following table:

	Before bloom. Per cent.	In full bloom. Per cent.	Seeds well formed. Per cent.	Ripe. Per cent.
Total organic matter	40	75	95	100
Ash	60	88	100	98
Total nitrogen	55	80	100	98
Calcium oxid	32	64	98	100
Potassium oxid	55	90	100	95
Phosphoric anhydrid	35	70	98	100

Minn. Expt. Sta. Bull. 47.

Maize (Corn)

353. **Importance.**—Since Indian corn or maize is grown over such a wide range of territory, and is used alike as animal and human food, and as animal food may serve as either grain or forage, a knowledge of the chemical changes which take place during its growth, and the composition of the plant at maturity, will enable the student to utilize this crop more economically in the feeding of farm animals. Some of the facts relating to the composition of corn at different stages of growth and the analyses given in this chapter are taken largely from Bulletin No. 9, Mo. Agr. Expt. Station.

354. **Roots.**—The function of the roots is to collect and assimilate and transport to other parts the nitrogen and mineral food from the soil. In mature corn, but a small amount of the essential elements of plant food are present in the roots, only sufficient for the structure of the root tissues. During growth, there is always some being transported to the parts above ground. At maturity, the dry matter in the roots constitutes about 5 per cent. of

the dry matter of the plant. The roots contain the largest amount of fiber and the smallest amount of fat of any part of the plant. Of the ash elements, soda is present in greater amounts than in parts above the ground. In the early stages of growth, the roots are very rich in iron, which decreases as the plant matures, because of its being given over to other parts. The nitrogen in the roots never, at any stage of growth, exceeds 1.25 per cent. of the dry matter. It is transported to the parts above ground more rapidly than any other element. During the last fifteen days of growth, there is but little mineral food, except magnesia, taken up, and there is a loss of about 12 per cent. of potash from the roots which indicates that the retrograde movement of potash at maturity may extend from the roots back to the soil. In the later stages of growth, there is a great influx of magnesia. Silica and the non-essential ash elements make up the larger portion of the ash elements in the mature plant.

355. **Stalk.**—The stalk, during growth, undergoes a decided change in composition; there is a gradual increase in the content of fiber and a decrease in proteids. The outside of the stalk has a different chemical composition from the pith. The largest per cent. of dry matter is found in the stalks from two to three weeks before maturity. As the plant matures, the proteid and circulatory carbohydrates are transferred to the seed. When mature, both the pith and stalk have a low protein, fat and digestible carbohydrate content, and hence a low feeding value. The pith is somewhat richer in nitroge-

nous matter than the stalk. The ash of the stalk is characteristically rich in silica.

356. Leaves.—Since all of the chemical compounds of the plant are first produced in the leaves, and then transported to other parts, it follows that the leaves at different stages of growth have a variable composition. Since the cells of the young leaves contain more protoplasm than mature leaves, the largest amount of nitrogenous matter is present there in the early stages of growth. As the plant matures, this nitrogenous matter is given up for the formation of other parts, and then there is a decline in the percentage amount of nitrogen in the leaves. The largest amount of dry matter in the leaves is found about six weeks before maturity. The plant as a whole, however, increases even more rapidly in dry matter after this time, but no additional organic matter accumulates in the leaves but is used for seed formation. As the plant matures, the total ash in the leaves steadily increases, due to silica, which is deposited there as inert material, while that in the stems declines. As the plant matures, the phosphorus content of the leaves declines, the phosphorus, like the nitrogen, being stored up in the seeds. The largest amount of potash in the leaves is at the time of the largest amount of dry matter, about six weeks before maturity. Next to the seed, the leaves contain the largest amounts of protein, fat, and digestible carbohydrates of any part of the plant. When green, the leaves have a higher nitrogen content than when yellow. The feeding value of corn fodder depends to a great extent upon the condition of the leaves.

357. **Tassel.**—The tassel has some of the chemical characteristics of the seed; it is concentrated in nitrogen, has less fiber, and an ash rich in phosphates. The flower stalks and anthers yield an ash in composition like that of the stems, while the ash of the pollen is nearly identical with that of the matured grain. The pollen is particularly rich in nitrogen. One of the claims made for detasseling corn, is to prevent loss of nitrogen and phosphoric acid through the pollen. It is estimated that the nitrogen removed in the pollen amounts to from 5 to 10 pounds per acre. The fresh and dried silk (stigmas) shows a decline in both nitrogen and phosphoric acid after fertilization.

358. **Husk.**—The husk when first formed has all of the materials for the development of the seed, and its composition at different stages of growth shows a gradual transfer of its constituents to the ripening grain. When fully mature, the husks are much poorer in ash and nitrogen than the leaves or stems, but are not so poor as the cob. The cob remains functionally active longer than any other part of the plant, and is composed largely of cellulose and pentose compounds, and contains but little protein or fat.

359. **Ripening Period.**—The corn plant, at first, absorbs its mineral food and nitrogen at a very rapid rate. In fact, there is but little mineral matter or nitrogen assimilated during the last few weeks of growth. The last stage of development is a period of rearrangement and transportation of the compounds from the leaves to the seed. The composition of the different parts of the corn plant when mature and of the ash is given in the following table:

	Roots.	Pith.	Outside.	Stems.	Leaves.	Pollen.	Tassel.	Anthers, empty.	Husk.	Cob.	Kernel.
Dry matter, weight in grams	14.2	195.6	145.8	209.8	124.6	6.0	20.5	15.5	85.5	135.6	320.2
COMPOSITION OF DRY MATTER.											
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Ash	2.9	2.5	2.2	1.6	8.1	2.4	4.6	6.1	6.2	1.5	1.3
Ether extract	0.5	1.3	1.0	0.5	0.7	1.1	...	3.3	0.8	1.1	4.5
Fiber	41.9	26.3	39.1	34.8	24.4	0.3	...	8.7	33.8	34.3	1.9
Protein	6.4	4.8	3.6	4.9	8.3	22.0	16.3	21.4	4.4	3.1	10.5
Non-nitrogenous	48.2	65.2	54.1	58.3	61.3	74.2	...	60.6	54.8	60.1	81.9
COMPOSITION OF ASH.											
Silica	32.1	7.1	30.4	21.6	39.0	0.7	2.2	2.7	37.8	25.0	6.8
Potash	37.7	48.4	38.3	46.8	30.5	37.8	49.8	50.1	40.8	51.2	38.2
Soda	4.4	0.1	1.8	2.6	2.6	2.8	2.7	0.9	2.7	0.8	0.5
Lime	5.6	11.1	8.0	8.0	12.8	6.9	3.0	2.9	6.4	1.8	2.0
Magnesia	4.0	8.1	11.1	5.2	7.5	10.9	9.2	10.4	7.7	5.5	16.0
Iron	0.2	0.5	0.4	0.3	1.0	3.1	0.3	0.4	0.3	0.2	0.3
Phosphoric acid	14.4	2.0	3.1	3.7	3.9	36.8	18.6	11.2	0.9	2.8	33.2

CHAPTER XXVII

Factors Which Influence the Composition and Feeding Value of Crops

The main factors which influence the composition and feeding value of crops are: (1) Seed, (2) soil, (3) climate, (4) stage of maturity, (5) method of preparation as food, and (6) combination with other foods.

360. Seed.—The composition and individuality of the seed influence the composition and feeding value of the forage crop produced. Heavy-weight seeds are usually more mature and contain a larger amount of reserve plant food than those of light weight (see Section 338). Experiments by Heilreigel show that the heavier the seed, the more vigorous the young plant. Where there was not an overabundance of plant food in the soil, the difference in vigor of plants was discernible even up to the time of harvest. Experiments at the Illinois Station (Bull. Nos. 53 and 55) show that by careful selection of seed corn, the percentage amount of nitrogenous matter in the grain may be increased from 0.5 to 1.25 per cent. Not all of the cereals respond as does corn to the influence of seed selection to produce variations in chemical composition.

The care and storage which the seed receives prior to planting also influences its vitality. When seed corn is stored in a damp or poorly ventilated place, the excessive amount of moisture results in injuring the vigor of the germ. Seed wheat is often injured by being stored in elevators where bin-burning caused by fermentation takes place. Sound heavy seeds of full maturity always give the best crop returns. Forage crops are more susceptible to seed influences than are grain crops, because the leaves and stems of plants are less constant in composition than is the seed.

361. Soil.—The condition of the soil as to available plant food has a material influence upon composition, and in promoting a balanced crop growth. Experiments conducted at the Connecticut Experiment Station (Storr's Annual Reports, 1898, 1899) show that fodder crops grown with a liberal supply of nitrogen have a tendency to contain more of the nitrogenous compounds than similar crops grown with a scant supply. The nitrogen and available mineral matter increase the activity of the protoplasm and chlorophyl in the production of all of the organic compounds. With a larger amount of available plant food, particularly nitrogen, a larger amount of foilage is produced. All foliage crops, grown upon rich soils, have larger leaves and a higher nitrogen content than those grown on poor soils.

The condition of the soil influences the composition of leaves and stems to a greater extent than it does the composition and character of the seeds because they are more constant in composition. The selection of seed corn has a greater influence upon the composition and feeding value of corn fodder than it has upon the grain. Fodder crops, produced upon fertile soils and under favorable climatic conditions have the highest feeding value. The condition of the soil, as to acidity or alkalinity, also influences the character and composition of crops. Crops produced upon acid soils have a different appearance from those grown upon mildly alkaline soils. An unbalanced condition of plant food in the soil produces an unbalanced crop growth. It is not possible, however, by the use of manures or the selection of seeds, to entirely change the composition of crops. In the extensive experiments by Lawes and Gilbert (Rothamsted Memoirs, Vol. III), the continued use of nitrogen and mineral manures for a period of twenty years showed no material increase in the amount of nitrogenous matter in the wheat. In similar experiments with potatoes, in which nitrogenous manures alone were used, there was an increase of 0.05 per cent. of nitrogenous matter. The sugar-beet has been extensively changed in composition by cultivation. The content of sugar has been increased from 8 to 16 per cent. Wheat and other grains show material differences in weight and composition when grown upon different types of soil. Experiments have been made where wheat grown from one lot of seed under different climatic and soil conditions showed a difference of 18 bushels per acre in yield, and 8 pounds per bushel in weight (Minn. Expt. Sta. Bull. No. 23). Forage crops produced upon soils of high fertility have a higher feeding value than crops grown upon poor soils. At the Minnesota Experiment Station, timothy and corn fodder grown on land that had been manured and rotated, and similar crops grown on unmanured land showed the following amounts of protein :

	Timothy hay grown on manured land. Per cent.	Timothy hay grown on unmanured land. Per cent.	Corn fodder grown on manured land. Per cent.	Corn fodder grown on unmanured land. Per cent.
Crude protein (dry matter basis) ...	8.75	6.45	8.85	6.32

362. Climate.—In the early stages of plant growth, the nitrogenous compounds are produced more abundantly than are the non-nitrogenous (Section 351). If the growing season is in any way cut short, the crop has a slightly larger amount of nitrogenous matter than if normal conditions prevail. Any shortening of the growing period or forcing of the crop to maturity lessens the per cent. of dry matter, increases the nitrogenous compounds, and decreases the carbohydrates. The composition of grains is influenced by climatic conditions, particularly at the time of seed formation when growth is often checked before all of the compounds have been transferred from the leaves to the seeds; shrunken or immature grain is the result. Such grain contains less starch and more nitrogenous compounds than that which has fully matured. Experiments with potatoes by Lawes and Gilbert show that they too are, to a slight extent, influenced in composition and starch content by climatic conditions; the longer the growing period, the larger the amount of starch. A short and forcing growing season, together with a fertile soil, has a tendency to produce crops of high nitrogen content.

363. Stage of Maturity.—Since all crops at first produce nitrogenous compounds in larger amounts than at later stages, it follows that early cut crops contain proportionally more nitrogen than those cut later. This increase in nitrogenous matter is, however, at the expense of the total dry matter in the crop. If crops are cut too early, that is, before early bloom, too much of the nitrogen is in the form of amides, some of which are changed to proteids at a later stage. Early cutting results in securing a smaller yield per acre of dry matter more concentrated in nitrogenous compounds. When fodder crops are cut at early or full bloom, the nutrients are more evenly distributed than at maturity when some of the proteids and carbohydrates have been transferred from the leaves to the seeds, leaving stems and leaves with a larger amount of fiber and less protein. The composition and comparative feeding value of clover cut at different stages of growth are given in Section 351.

364. Method of Preparation as Food.—The method of curing and preparing a fodder affects its food value. Overdrying causes a mechanical loss of leaves which gives the fodder a different composition and feeding value from that when the leaves are all secured. Bleaching results in partial destruction of the chlorophyl and a loss of the essential oils that impart palatability. Other chemical changes which have a tendency to make the fodder less digestible also take place. A mechanical loss of leaves and exposure to leaching rains result in a loss of nutritive value. The materials extracted are the most soluble and digestible. A heavy, leaching rain may extract 10 per cent. or more of the nutrients, making the leached fodder less available and less palatable.

The method of storing and the mechanical condition of a fodder also influence, to a limited extent, the availability of the nutrients. The influence which the combination of fodders has upon digestibility and food value is discussed in Chapter XXXV.

365. Improving the Feeding Value of Forage Crops.—The main factors, as seed, fertility of soil, stage of maturity, and care which the fodder receives, are all under the control of the farmer, climate being the only factor that is not directly controllable. Lack of moisture in dry seasons can, however, in part, be overcome by shallow cultivation. By careful selection of seed, conserving the fertility of the soil, and suitable methods of cultivation and storage, it is possible not only to increase the yield but also to change the chemical composition and feeding value of forage crops. As yet, experiments have not demonstrated the extent to which all crops are susceptible to these influences.

CHAPTER XXVIII

Composition of Coarse Fodders

366. The Term Coarse Fodders is applied to animal foods which usually contain large amounts of crude fiber, and, while bulky in nature, are essential foods, many of them having a high nutritive value. A coarse fodder may be either green or field-cured ; pasture grass, timothy hay, and corn fodder are all examples of coarse fodders. The proteid content of coarse fodders ranges from 4 per cent. and less, in straw, to 12 per cent. and more, in clover and legumes.

367. Straw.—The straw from wheat, oats, barley, and rye contains from 36 to 38 per cent. of crude fiber, and less than 4 per cent. of crude protein, oat straw being the richest. The amount of fat in straw is small, rarely exceeding 1.5 per cent. Straw contains from 6 to 9 per cent. of water. The pentose compounds make up a large portion of the nitrogen-free extract. Straw is a food poor in protein, fat and digestible carbohydrates, and contains a high per cent. of ligno-cellulose, pentose, and ash materials. Straw may produce some heat in a ration, but for the production of muscle or the repair of proteid matter, it occupies about

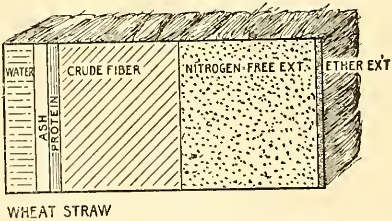


Fig. 84.—Composition of a bale of wheat straw.

the lowest place in the list of animal foods. The various factors which influence the composition of plants (see Chapter XXVII) affect the composition of the straw. That from grain immaturely ripened has higher feeding value than from grain fully ripened, because in the unripe state less of the nutrients have been removed for seed formation. The greener the straw, the higher its food value.

368. Timothy Hay.—Timothy hay has more protein, but in many respects the same general characteristics as straw. The per cent. of fiber usually ranges from 28 to 32 per cent. or more, which is from 6 to 10 per cent. less than in straw. The amount of crude protein ranges from 5.5 to 9 per cent. according to the conditions under which the crop was grown. Average timothy hay contains 7.5 per cent. which is about twice as much as found in straw. The amount of ether extract is about 2.25 per cent., of which a large portion is non-fatty material. As in the case of straw, the nitrogen-free extract of timothy consists largely of pentose bodies; there is also a small amount of soluble carbohydrates. While timothy hay is not rich in protein, it is a valuable fodder, particularly when one of fair energy-producing power is desired, as for feeding work horses.

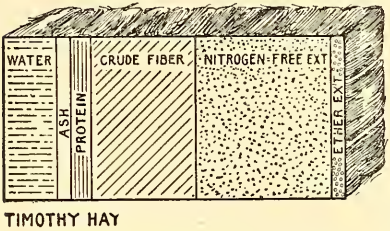


Fig. 85.—Composition of a bale of timothy hay.

369. Hay, Similar to Timothy.—Millet, blue grass hay, and the numerous varieties of native prairie hay, have about the same general composition and feeding value as timothy hay. Each, however, differs from timothy to a slight extent both in chemical composition and structure of parts, some being preferable to others for feeding certain kinds of animals. These hays, particularly native prairie hays, vary in protein content from 6 to 11 per cent. according to the conditions under which they are grown and other factors which affect their composition. Timothy, blue grass and the numerous varieties of prairie hay, are classed as coarse fodders containing a low to a medium amount of crude protein.

370. Oat Hay.—When oats are cut at the heading-out stage and cured as hay, they make a valuable fodder which compares favorably with the best grades of timothy hay, and usually contains slightly more protein than timothy or hays of similar character. Oat hay should be cured for fodder while the nutrients are evenly distributed, and before they are transported and stored up in the grain.

371. Hay, Similar to Oat Hay.—Wheat and other cereals, cut at the right stage, have a similar composition and feeding value to oat hay. In localities where the climatic conditions do not admit of the growth of perennial grasses, these forage crops are grown in their stead.

372. Bromus Inermis varies in composition and feeding value according to the stage when cut. When overripe, its protein content is between that of straw and timothy hay. If cut or pastured while young, it has a high feeding value. In this crop, the non-nitrogenous compounds, particularly fiber, are formed at a rapid rate in the last stages of growth.

373. Clover Hay is characteristically rich in crude protein, containing nearly twice as much as poor grades of timothy. It also contains less crude fiber and more ether extract. The large amount of crude protein and other nutrients makes it one of the most valuable fodders that can be produced for growing, fattening, or milk-giving animals. There is no coarse fodder except alfalfa that has so high a protein content as clover when grown and cured under the best conditions. Clover ash is of different composition from that of timothy. It contains a small amount of silica and a large amount of lime, while timothy ash contains a large amount of silica and a relatively small amount of lime. The nitrogen-free extract of clover is largely pentose materials. The composition and comparative feeding value of early- and late-cut clover are given in Section 351. In curing clover hay, it should be the aim to prevent mechanical losses of leaves during the handling of the crop. When clover hay is fed to stock, less grain and milled products are required than when hays of lower crude protein content are used. There are a

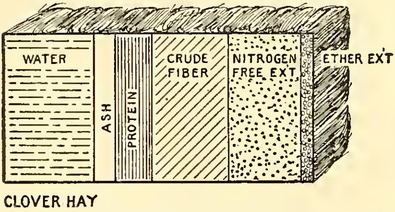


Fig. 86.—Composition of a bale of clover hay.

number of varieties of clover; alsike, crimson, scarlet and white clovers, all having about the same general composition. Each, however, has characteristic habits of growth which makes it peculiarly adapted to certain soil and climatic conditions.

374. **Alfalfa and Fodders Similar to Clover.**—Alfalfa has somewhat the same general composition and feeding value as clover, but its physical composition, as density of tissue and proportion of leaves to stems is different. It can be grown under different and more adverse climatic conditions. All members of the leguminous or pulse family, to which clover, alfalfa, peas, cow peas and vetch belong, are characteristically rich in protein, and are among the most valuable forage crops that can be produced. The discovery, by Heilreigel, of the unique value of clover and other legumes in assimilating the free nitrogen of the air by means of the action of micro-organisms associated with the roots of these plants, and of the use of leguminous crops in increasing the supply of nitrogen in the soil, is one of the greatest achievements of agricultural chemistry. In Plate III, the arrow indicates one of the nodules which contain the nitrogen-assimilating organisms.

375. **Rape.**—The rape plant contains nearly as much crude protein as clover hay. Because of the presence of certain volatile oils, it cannot be fed to milk-cows without imparting an unpleasant taste to the milk. Rape, however, is valuable for the feeding of all growing and fattening animals.

376. Pasture Grass.—In the study of the composition of plants at different stages of growth, it was stated that the nitrogenous compounds are produced more rapidly than the non-nitrogenous (Section 351). The dry matter of pasture grass is more nitrogenous in character than that of the matured crop. The dry matter of all kinds of pasture grass is rich in crude protein; the various nutrients, however, range between wide limits, according to the species of grass, and the conditions affecting its growth. When a piece of land is grazed, a smaller amount of total nutrients is secured than if a forage crop were harvested and fed. In pasturing, the results are similar to a series of early cuttings, before bloom, rather than one later cutting as in harvesting a crop.

377. Corn Fodder and Stover.—By corn fodder is meant the entire corn plant with or without ears, according to the conditions under which it has been grown, while corn stover is the plant after the grain has been removed. Corn fodder is one of the most valuable, palatable, and largest yielding crops that can be procured. When sown so that no ears, or very small ones, are developed, the leaves and stalks contain all of the nutrients which would otherwise be stored up in the seed. When grown under favorable conditions, corn fodder contains about the same per cent. of crude protein and is equal in value to the best quality of timothy hay. When field-cured, it contains from 15 to 30 per cent. of water, from 12 to 25 per cent. of crude fiber, and from 2.5 to 4 per cent. of ash. In the study of the composition of the corn plant (Chapter XXVI), the content of crude protein and other nutrients in the various parts of the plant was considered. In the production of corn fodder, it should be the aim to produce a large number of mediumly small plants with large leaves, small or no ears and small stalks. By so doing, the largest amounts of nutrients most evenly distributed, palatable, and digestible are secured. Corn stover has more of the characteristics of a straw crop, and is not as valuable as corn fodder. When ears are produced, the protein is stored up in the grain, and hence less is found in stalks and leaves. The physical condition and chemical form of the cellulose, as hydrated or lignose, also influence the feeding value of corn fodder and corn stover. Corn fodder can be fed to all kinds of farm animals, and is one of the cheapest forage crops that can be grown. It is valuable alike for horses, sheep, and dairy and beef cattle.

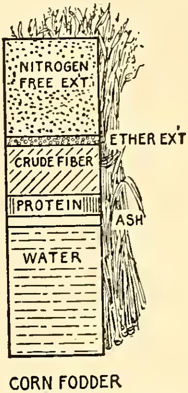


Fig. 87.—Composition of a shock of corn fodder.

378. Silage.—When silage is prepared, the green material is placed in a nearly air-tight compartment. Corn, clover, or any green crop may be cured as silage. Corn, however, is the crop most generally given this treatment and unless otherwise designated, silage usually has reference to corn fodder prepared in this way.

The chemical changes that take place in the silo are caused mainly by ferments. Carbon dioxid, hydrocarbons, and ammonia in small amounts are among the volatile products formed. There is always a loss of dry matter in curing silage. This is greatest in the top layer and least in the bottom. The losses in the different sections of a large silo may range from 5 to 25 per cent. In a large silo the losses are less than in a small one, and they need not exceed 5 per cent. of the dry matter.

The average of a number of trials shows that when corn fodder is prepared as silage, there is a loss of from 5 to 25 per cent. of dry matter, of which a proportional amount is protein. Including mechanical losses, there is nearly the same loss in the field curing of corn fodder as in its preparation as silage.

The temperature of the silage, when undergoing fermentation, ranges from 35° to 75° C. The lower temperatures generally produce poor silage, while the higher produce a better quality. In order to produce sweet silage, the conditions should be such that the temperature during fermentation is kept above 43° C., so as to render the acid spore that produces the sour silage less active and to allow other ferments to act. No appreciable amount of alcoholic fermentation takes place in the silo. In the production of silage, the corn should be cut in a green condition rather than when overripe, and evenly packed in the silo so that all parts will ferment alike. Comparatively short fermentation at a high temperature is preferable to slow fermentation at a low temperature.

AVERAGE COMPOSITION OF AMERICAN FODDERS.
(Jenkins and Winton.)

Field-Cured Fodders.	Water. Pct.	Ash. Pct.	Protein (N × 6.25). Pct.	Crude fiber. Pct.	Nitrogen-free ex't. Pct.	Ether ex't. Pct.
Corn fodder, average	42.2	2.7	4.5	14.3	34.7	1.6
“ “ minimum	22.9	1.5	2.7	7.5	20.6	0.6
“ “ maximum	60.2	5.5	6.8	24.7	47.8	2.5
“ leaves, average	30.0	5.5	6.0	21.4	35.7	1.4
“ “ minimum	14.8	4.3	4.5	17.4	27.3	0.8
“ “ maximum	44.0	7.4	8.3	27.4	44.1	2.2
“ stalks, average	68.4	1.2	1.9	11.0	17.0	0.5
“ “ minimum	51.3	0.6	1.2	6.9	11.2	0.3
“ “ maximum	78.5	2.0	3.0	16.8	26.0	1.0
“ stover, average	40.1	3.4	3.8	19.7	31.9	1.1
“ “ minimum	15.4	1.7	1.8	14.1	23.3	0.7
“ “ maximum	57.4	7.0	8.3	32.2	53.3	2.2
Redtop	8.9	5.2	7.9	28.6	47.4	1.9
Timothy:						
All analyses	13.2	4.4	5.9	29.0	45.0	2.5
Cut in full bloom	15.0	4.5	6.0	29.6	41.9	3.0
Cut soon after bloom	14.2	4.4	5.7	28.1	44.6	3.0
Cut when nearly ripe	14.1	3.9	5.0	31.1	43.7	2.2
Red clover	15.3	6.2	12.3	24.8	38.1	3.3
Alsike clover	9.7	8.3	12.8	25.6	40.7	2.9
White clover	9.7	8.3	15.7	24.1	39.3	2.9
Alfalfa	8.4	7.4	14.3	25.0	42.7	2.2
Cow pea	10.7	7.5	16.6	20.1	42.2	2.9
Wheat straw	9.6	4.2	3.4	38.1	43.4	1.3
Oat straw	9.2	5.1	4.0	37.0	42.4	2.3
Green Fodders.						
Corn fodder (Flint) average	79.8	1.1	2.0	4.3	12.1	0.7
“ “ “ minimum	51.5	0.7	0.6	2.1	4.3	0.3
“ “ “ maximum	90.8	1.8	4.0	11.4	36.3	1.3

Green Fodders (*continued*).	Water. Pct.	Ash. Pct.	Protein (N × 6.25). Pct.	Crude fiber. Pct.	Nitrogen-free ex't. Pct.	Ether ex't. Pct.
Corn fodder (Dent) average	79.0	1.2	1.7	5.6	12.0	0.5
“ “ “ minimum	59.5	0.6	0.5	2.0	3.0	0.1
“ “ “ maximum	93.6	2.5	3.8	11.0	27.0	1.6
“ “ (Sweet varieties)	79.1	1.3	1.9	...	12.8	0.5
“ “ (All varieties)	79.3	1.2	1.8	5.0	12.2	0.5
Redtop in bloom	64.8	2.3	3.3	9.4	19.1	1.2
Timothy	61.6	2.1	3.1	11.8	20.2	1.2
Kentucky blue grass	65.1	2.8	4.1	9.1	17.6	1.3
Legumes:						
Red clover	70.8	2.1	4.4	8.1	13.5	1.1
Alfalfa	71.8	2.7	4.8	7.4	12.3	1.0
Cowpea	83.6	1.7	2.4	4.8	7.1	0.4
Soja bean	74.8	2.4	3.0	7.3	11.5	1.0
Silage:						
Corn	79.1	1.4	1.7	6.0	11.1	0.8

CHAPTER XXIX

Wheat

379. Structure of Kernel.—The wheat kernel has three distinct coverings (see Fig. 88): (1) The outer cuticle or pericarp which is a hard tough coat, composed largely of ligno-cellulose; this is the seed pod in which the seed is enclosed, and constitutes the main part of the bran. (2) An inner double cuticle of cellular tissue which is called the episperm and consists of two hard coats called respectively the inner and outer integument ; this double skin or layer may be considered one coat and forms a part of the bran. (3) A third, hard, thin skin or layer called the perisperm. The three bran coats constitute about 5 per cent. of the weight of the grain. Within these three bran layers is a single layer of large cells called the aleurone layer. This is sometimes erroneously called the

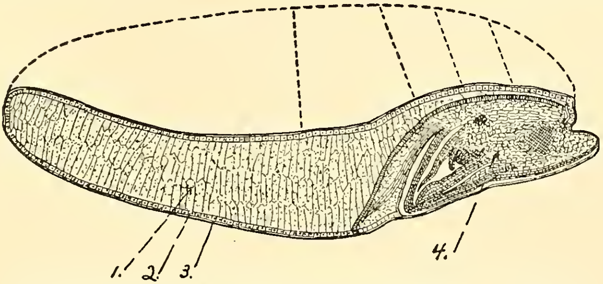


Fig. 88.—Structure of wheat kernel: 1, Floury portion; 2, aleurone layer; 3, the bran composed of three layers; 4, germ (adapted from Bull. 32, Neb. Station).

gluten layer. The germ or embryo plant is present in the lower part of the kernel and opposite the rounded end. The germ constitutes about 6 per cent. of the weight of the kernel. The main part of the seed is the endosperm which is the floury portion, sometimes incorrectly spoken of as the starch cells, in reality composed of starch, gluten, mineral matter, and other compounds in small amounts. Additional information in regard to the structure of the wheat kernel is given in Bulletin No. 32 of the Nebraska Experiment Station.

380. Proteids of Wheat.—Wheat contains the largest amount of proteids of any of the cereals, and also proteids of an entirely different character. There are five separate proteids in wheat: (1) An albumin (leucosin), (2) a globulin (edestin), (3) a proteose, and two insoluble proteids called (4) gliadin, and (5) glutenin, which together constitute the gluten. Wheat gluten can be obtained by washing a sample of dough from wheat meal or flour with water to remove the starch and other non-gluten compounds. The gluten mass from hard wheat is usually elastic and tenacious, varying in quality according to the nature of the wheat from which it was obtained. The milling qualities of wheat, and the baking qualities of flour are determined largely by the composition of the gluten.

Wheat gluten is composed of two proteids, gliadin and glutenin; these form about 85 per cent. of the proteids of wheat. The gliadin may be extracted from either gluten or flour with a 70 per cent. solution of alcohol, and is obtained, after evaporating the alcohol, in the form of thin, transparent flakes which resemble gelatin. In fact, gliadin was called by the earlier investigators, plant gelatin. When moistened, the gliadin expands and forms a mucilagenous mass. When more water is added, a small amount is dissolved. Gliadin is soluble in dilute acid and alkali solutions ; in many wheats, particularly those which have undergone slight fermentation, there is sufficient acid developed to combine with and render soluble appreciable amounts. Gliadin, like all of the wheat proteids, is characterized by a high per cent. of nitrogen. Gliadin takes a very important part in bread-making, and is the material which binds together the flour to form dough and enables the mass to expand, retaining the gas generated by the yeast. Wheat gluten contains from 60 to 70 per cent. of gliadin and from 30 to 40 per cent. of glutenin.

Glutenin is the proteid which remains after extracting the gliadin from the gluten. When dry and pure, it forms a light gray mass which may be reduced to a fine powder. Glutenin is insoluble in dilute alcohol and salt solutions and is only sparingly soluble in water, but is readily soluble in dilute acid and alkali solutions. This proteid also takes an important part in bread-making. It combines mechanically with the gliadin and, "serving as a nucleus to which the gliadin adheres," prevents the dough from becoming too soft and sticky. When these two proteids are present in the proportion of about 65 per cent. of gliadin to 35 per cent. of glutenin, a much better quality of bread can be produced than from flour containing the same amount of total proteids but of which 75 per cent. is gliadin and 25 per cent. glutenin. Two samples of wheat may contain the same amount of gluten, and the flour from one produce good bread, while that from the other is of very poor quality. The most valuable wheats for bread-making purposes are those in which 80 to 85 per cent. of the protein is gluten, and the gluten is composed of from 60 to 65 per cent. gliadin and 35 to 40 per cent. glutenin. A wheat may produce a good quality of bread and at the same time contain a low per cent. of protein, while, on the other hand, poor bread-making qualities can be associated with a high per cent. of protein. Glutens which are usually considered the most valuable for bread-making purposes are hard, elastic, and of a light yellowish tinge. Poor gluten is dark in color, has an uneven surface, possesses but little power to recoil, and is very sticky.

Experiment 69.—Gluten from wheat flour. To about 30 grams of flour made from hard spring wheat, add sufficient water to form a stiff dough and allow it to stand for half an hour, in order that the physical properties of the gluten may develop. Place the dough in a cloth and work it gently with the fingers, while a stream of water is allowed to flow over it. Continue the washing until the water that runs away is clear, which indicates that all starch has been washed out of the dough. The washing may be completed with the mass in the hand. Leave this gluten in water until the gluten from flour made from soft winter wheat has been prepared. Compare the two samples of gluten.

Questions. (1) What is wheat gluten? (2) Describe hard wheat gluten. (3) How does it differ from soft wheat gluten? (4) How do the two moist glutens compare as to weight? (5) Which gluten contains the larger amount of gliadin? (6) Which is the better quality of gluten for bread-making purposes?

Experiment 70.—Gliadin from flour. Place in a flask 10 grams of flour, 30 cc. of alcohol, and 20 cc. of water. Cork the flask and shake, and after a few minutes shake again. Allow the alcohol to act on the flour for an hour or until the next day. Then filter off the alcohol solution and evaporate the filtrate to dryness over the water-bath. Examine the residue. To a portion add a little water. Burn a little. Treat a little in a test-tube with water containing a few drops of HCl.

Questions. (1) Describe the appearance of the gliadin. (2) What was the result when water was added? (3) When burned, what was the odor of the gliadin, and what does this indicate? (4) What effect did the dilute HCl have upon the gliadin? (5) What is gliadin?

Composition of Wheat Gluten

	Protein (N. × 5.7).	Gliadin and glutenin.	Gliadin.	Glutenin.	Per cent. of gluten in form of	
					Gliadin.	Glutenin.
1. Scotch fife	14.76	12.46	7.26	5.20	58.3	41.7
2. Wellman's fife	12.60	10.18	6.14	4.04	60.3	39.7
3. Red winter wheat	10.73	8.68	5.60	3.08	64.5	35.5
4. Early Genesee winter	7.98	6.31	3.71	2.60	58.8	41.2
5. Ladoga	9.54	8.25	5.64	2.61	68.5	31.5
6. Blue stem	14.20	11.75	7.84	3.91	66.7	33.3
7. Crimean	11.08	9.49	5.77	3.72	60.8	39.2
8. Frosted spring wheat	12.88	6.39	4.25	2.14	66.5	33.5
9. Calcutta (India)	8.13	6.70	4.90	1.80	73.1	26.9
10. No. 1 Chili	7.01	5.62	2.92	2.70	52.0	48.0
11. La Plata (Argentine Rep.)	13.38	11.84	4.99	6.85	42.1	57.9
12. Nicolaeff Azima (Russia)	10.28	8.74	5.70	3.04	65.2	34.8
13. Oregon white winter	9.23	7.65	5.42	2.23	70.8	29.2
14. No. 2 red winter wheat	7.01	5.56	3.77	1.79	67.8	32.2
15. No. 2 hard winter wheat	8.83	7.31	3.99	3.32	54.6	45.4

381. Relation of Nitrogen in Wheat to Nitrogen Content of Flour.—Medium-sized, well-formed wheat kernels usually contain more nitrogen and gluten than large, rotund kernels. The size of the germ, the proportion of aleurone to endosperm, and the nitrogen content of the endosperm or floury portion are the three factors which determine the relation of the nitrogen in the wheat to the nitrogen in the flour. Ordinarily, the germ makes up about 7 per cent. of the weight of the kernel, and the endosperm from 82 to 86 per cent. When the amount of endosperm is increased, there is proportionally less germ, and aleurone, and a larger amount of flour is secured. The size of the wheat kernel together with the size of the indentation marking the germ area indicate approximately the amount of germ in the kernel. The larger the amount of germ and aleurone, the smaller the amount of flour recovered when the wheat is milled. As a general rule, wheats which contain the largest amount of nitrogen produce the most nitrogenous flours, but the total nitrogen in the wheat cannot always be taken as an index of that in the flour. Two wheats frequently contain about the same total nitrogen but the nitrogen is distributed differently in each; in one a larger portion is present in the germ and aleurone, and in the other a larger amount is in the endosperm and hence recovered as flour. In the following table, the per cent. of protein in the grain and that in the patent flour recovered by the modern roller process of milling are given. These tests were made under the supervision of the author in two of the large flour mills of Minneapolis, Minn. The percentage amounts of wheat recovered as patent flour were about the same in all of the tests.

PER CENT. OF PROTEIN.

Mill B

Wheat.		Flour.
15.19		14.60
15.44		14.13
15.75		14.00
	Mill C	
15.50		13.90
15.38		14.65
14.33		13.88
15.51		14.44
15.00		13.94
15.15		14.06
15.33		12.50
15.00		12.56
15.19		14.19

382. Influence of Fertilizers upon Composition of Wheat.—Experiments by Lawes and Gilbert (Rothamsted Memoirs, Vol. III) show that the different kinds of manure, as nitrogenous, mixed and mineral, influence the yield but not materially the composition of the grain. During the time of the experiment, covering a period of twenty years, the nitrogen, phosphoric acid, and potash in the dry matter of the grain were fairly constant, and when different manures were used, there were no greater variations in the composition of the grain than were observed between crops upon the same plots similarly manured during different seasons. Climatic conditions influenced the composition of the kernel to a greater extent than did fertilizers.

383. Variations in Composition of Wheat.—In Jenkins' and Winton's "Average Composition of American Feeding Stuffs," spring wheat is given as containing 12.5

per cent. protein and winter wheat 11.8 per cent. In both spring and winter wheat, variations in protein from 8 to 16 per cent. are noticeable. While average wheat contains 12.5 per cent., some samples contain as low as 8 and others as high as 18 per cent.

The greatest differences in composition are noticeable when wheat grown at different seasons is compared. Five samples of the 1891 crop of wheat analyzed by the Minnesota Experiment Station contained 12.01 per cent. of protein. The wheat was of unusually high milling and baking value. In 1892, six samples from the same localities showed 13.22 per cent. of protein, and in 1901, 14 samples contained 15.21 per cent.

Some of the effects of climate and soil upon the physical and chemical properties of wheat are noted in Bulletin No. 18, Part 9, Division of Chemistry, U. S. Department of Agriculture, from which the following paragraphs are taken:

"The inherent tendency to change which is found in all grains is most prominent in wheat; it may be fostered by selection and by modifying such of the conditions of environment as it is in the power of man to effect. The most powerful element to contend with is the character of the season or unfavorable climatic conditions. The injury done in this way is well illustrated in Colorado, and it would seem advisable in such cases to seek seed from a source where everything has been favorable, and begin selection again. It must be borne in mind that selection must be kept up continuously, and that reversion takes place more easily than improvement. It took but one season to seriously injure Professor Blount's wheats, but it will be two or more years before they have recovered from that injury. Hallett, in England, was able to make his celebrated pedigree wheat by selection, carried on through many years, but the same wheat grown by the ordinary farmer under unfavorable conditions for a few years without care has reverted to an ordinary sort of grain.

"The effect of climate is well illustrated by four specimens of wheat which are to be seen in the collection of the Chemical Division. Two of these were from Oregon and Dakota some years ago, and present the most extreme contrast which can be found in this variable grain. One is light yellow, plump and starchy, and shows on analysis a very small per cent. of albuminoids; the other is one of the small, hard, and dark-colored spring wheats of Dakota, which are rich in albuminoids. Between these stand two specimens from Colorado, which have been raised from seed similar to the Oregon and Dakota wheat. They are scarcely distinguishable except by a slight difference in color. The Colorado climate is such as to have modified these two seed wheats, until after a few years growth they are hardly distinguishable in the kernel. All localities having widely different climates, soils, or other conditions produce their peculiar varieties and modify those brought to them. The result of these tendencies to change and reversion from lack of care in seed selection or other cause has led to the practice of change of seed among farmers. A source is sought where either through greater care or more favorable conditions the desired variety has been able to hold its own. Sometimes this change is rendered necessary by conditions which are beyond the power of man to modify. As an example, No. 10 of Professor Blount's wheats, known as "Oregon Club," a white variety from Oregon, has been deteriorating every year since it has been grown in Colorado, whereas if the seed had been supplied every season directly from Oregon, the quality would probably have remained the same. In extension of this illustration the fact may be mentioned that the annual renewal of the seed from a desirable and favorable source often makes it possible to raise cereals where otherwise climatic conditions would render their cultivation impossible through rapid reversion. This is particularly the case with extremes in latitude, the effect of which is not founded so much upon the composition of the crop as on the yield and size of the grain."

384. **Storage of Wheat in Elevators.**—When new wheat is stored in elevators, a fermentation change takes place known as "sweating." This affects, to a slight extent, the chemical composition and milling qualities of the grain. When wheat is not fully matured or is damp, the fermentation which takes place causes the temperature to rise to 140° or more and occasionally high enough to cause spontaneous combustion. Thoroughly sound wheat undergoes but little change in temperature even when stored in large elevators where 120,000 bushels are placed in one compartment. The changes which take place during storage are brought about by the enzymes or soluble ferments in the grain, and the organized fer-

ments and moulds that are present on the surface of the grain. When wheat has been thoroughly cleaned, it does not readily undergo fermentation, while uncleaned, damp and unsound wheats deteriorate.

385. Grading of Wheat.—Wheat is graded entirely upon the basis of its physical properties, as: Weight per bushel, size and appearance of the kernels, freedom from foreign seeds, soundness of the kernel and absence of blemishes caused by frost, bleaching, sun scalding or sprouting. The spring and winter wheat grades established for the 1902 crop by the Minnesota Railroad and Warehouse Commission, are as follows:

No. 1 hard spring wheat must be sound, bright and well cleaned, and must be composed mostly of hard Scotch fife, and weigh not less than 58 pounds to the measured bushel.

No. 1 northern spring wheat must be sound and well cleaned, and must be composed equally of the hard and soft varieties of spring wheat, and weigh not less than 57 pounds to the measured bushel.

No. 2 northern spring wheat must be sound and reasonably clean, this grade to include all wheat not suitable for the higher grades on account of smut, barley, or too much king heads, cockle and oats, or any other defects, and to weigh not less than 56 pounds to the measured bushel.

No. 3 spring wheat shall comprise all inferior shrunken spring wheat weighing not less than 54 pounds to the measured bushel.

Note. Hard, flinty wheat, of good color, containing no appreciable admixture of soft wheat, may be admitted into the grade of No. 2 northern spring and No. 3 spring wheat, provided the test weight of the same is not more than one pound less than the minimum test weight required by the existing rules for said grades, and provided further that such wheat is in all other respects qualified for admission into such grades.

Rejected spring wheat shall include all spring wheat grown badly bleached, or for any other cause unfit for No. 3 wheat.

Note. Wheat containing admixture of "rice" or "goose" wheat will in no case grade better than rejected.

"No grade" wheat. All spring wheat that is in a heating condition, too musty or too damp to be safe for warehousing, or that is badly bin-burnt, badly damaged, exceedingly dirty, or otherwise unfit for storage shall be classed as "no grade" with inspector's notation as to quality and condition.

Note. The amount of dirt in all wheat shall be determined by the inspectors.

No. 1 white winter shall be sound, well cleaned, reasonably plump, and composed of the white varieties.

No. 1 winter to be sound, well cleaned, reasonably plump, and composed of the mixed white and red winter.

No. 2 winter to be sound, reasonably clean, and composed of the mixed white and red winter.

No. 3 winter shall comprise all winter wheat fit for warehousing, weighing not less than 54 pounds to the measured bushel, not sound enough or otherwise unfit for No. 2 of the other grades.

Rejected winter, fit for warehousing but otherwise unfit for No. 3.

386. Composition of Unsound Wheat.—When wheat fails to fully mature or is affected by frost, fungus disease, as rust or smut, or excessive heat causing bleaching, the composition of the kernel is affected. Such wheats usually contain a larger percentage of soluble carbohydrates, organic acids, and soluble proteids than fully matured wheat. Generally, the percentage amount of protein is higher although sometimes it is lower than in normal wheat. Wheat which has been damaged by bleaching, frost or fungus disease gives a lower yield of flour with poorer keeping and bread-making qualities.

Sound wheat of high milling qualities usually contains not more than 0.25 per cent. of acid bodies, less than 2 per cent. of soluble carbohydrates, and 1 per cent. soluble proteids.

387. Composition of Different Varieties of Wheat.—The different varieties of wheat, as spelt and durum, are similar in composition to ordinary wheat with minor variations in protein and fiber content. Spelt has a chaffy covering which gives it somewhat the same proximate composition as barley, but when the chaff is removed the seed has about the same general composition as wheat. In durum, the percentage of protein varies with the conditions under which the grain is grown. In the table given at the close of this chapter, it will be seen that durum has about the same content of proteid matter and other nutrients as hard spring wheat grown under similar conditions.

Experiment 71.—Grading wheat. Make the following tests with three samples of wheat. (1) Obtain the weight per quart (dry measure), and then calculate the weight per bushel of each. (2) Weigh 100 kernels of each sample. (3) Place ten representative kernels (of each) end to end and measure the length in millimeters and inches. (4) Note the color and appearance of each sample. (5) Observe if the kernels are "well filled;" (6) free from weed seeds and if there are any indications of smut, frosting, or bleaching. (7) Assign a grade to each sample (see Section 385).

388. American and Foreign Wheats.—A compilation of analyses of wheats and other cereals grown in different countries has been made by König. Absolute comparisons as to composition cannot be made because of numerous local factors which affect the wheat, as climate and soil. As great a difference is found in the composition of wheats raised in various parts of the United States, as between wheats of different countries where there exist similar varieties of climate and soil. In the case of American wheats, the tables given were compiled before any large number of Northwestern wheats were analyzed, hence the protein content is low because so small a number of wheats of highest protein content are included in the averages. In general, the tables of analyses show that wheat grown in tropical climates is less nitrogenous than that grown in more northern latitudes on equally fertile soils. In making use of the figures given in the following tables, it should be remembered that the comparisons are only relative as some of the samples contain a much larger amount of moisture than others, and an equal number, or samples proportional to the wheat-growing regions, are not included in the averages.

389. Wheat as Animal Food.—Wheat is not generally used for fattening farm animals because of its high value as human food. Occasionally, however, it is more economical to use it in preference to other grains for the feeding of stock. Experiments have shown that it has a high feeding value. As a food for growing pigs, it is somewhat preferable to corn ; for fattening pigs, there is but little difference between wheat and corn. The best results, however, are obtained when wheat is ground and fed with other grains. A mixture of equal parts of ground wheat and corn gives better results than when either wheat or corn is fed alone. When the price of wheat is low and it can be purchased for the same or less per pound than corn, it will pay to use wheat for feeding farm animals. As a food for dairy animals, ground wheat is fully equal to either corn or a mixture of corn and barley, and when fed to fattening steers, ground wheat produces about the same results as ground corn.

390. Wheat as Human Food.—Wheat is used as human food more extensively than any other cereal. This is due largely to its being produced over wider ranges of latitude and its containing proteids specially adapted to bread-making. With the exception of rye, wheat is the only grain which contains gliadin, the proteid which forms the dough and with the gas causes expansion of the mass during the process of bread-making.

COMPOSITION OF WHEAT

(Mainly from Jenkins & Winton, Bull. II, U. S. Dept. Agr., Office of Expt. Sta.)

	Water. Pct.	Crude protein. Pct.	Ether ex't. Pct.	Nitrogen-free ex't. Pct.	Crude fiber. Pct.	Ash. Pct.
Wheat, spring	10.4	12.5	2.2	71.2	1.8	1.9
Wheat, spring (max.)	13.4	15.4	2.6	78.7	2.3	2.6
Wheat, spring (min.)	8.1	8.1	1.8	66.1	1.3	1.5
Wheat, winter	10.5	11.8	2.1	72.0	1.8	1.8
+ Wheat, spelt[1]	10.0	11.3	2.3	63.9	9.2	3.3
+ Wheat, durum[2]	10.7	15.0	2.4	(69.9)		2.0
+ Wheat, No. 163[3]	11.2	15.8	2.3	(68.8)		1.9

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[1] Minn. analyses.

[2] Average of thirteen northern grown samples.

[3] Spring wheat grown under similar conditions as durum.

American and Foreign Wheats.	Moisture. Per cent.	Proteids. Per cent.	Ether extract. Per cent.	Crude fiber. Per cent.	Ash. Per cent.	Carbohydrates excluding fiber. Per cent.
Samples of miscellaneous origin (428)	13.37	12.51	1.70	2.56	1.79	68.01
Samples from northeast and middle Germany (90)	14.01	10.93	1.65	2.12	1.92	70.01
Samples spring wheat (81)	14.75	11.23	2.03	2.26	2.52	68.61
Samples from west and south Germany (52)	13.18	12.29	1.71	2.82	1.85	67.96
Samples spring wheat (30)	13.80	14.95	1.56	...	2.19	67.93
Samples from Austria-Hungary (18)	11.72	12.66	1.99	3.39	1.75	66.84
Samples from Russia, spring wheat (39)	12.65	17.65	1.58	...	1.66	65.74
England (22)	13.41	10.99	1.86	2.90	1.67	69.21
Scotland (16)	11.37	10.58	1.73	...	1.55	72.77
France (70)	15.20	12.64	1.41	2.00	1.66	68.92
Denmark (4)	13.95	9.36	2.34	2.19	1.34	71.40
Spain (9)	13.37	12.45	1.92	...	1.80	....
Africa (34)	11.80	11.18	1.83	1.82	1.76	70.04
Asia (8)	12.57	11.09	2.10	1.94	1.46	70.84
Australia (4)	13.37	10.16	1.39	...	...	....
North America (504)	9.92	11.60	2.07	1.70	1.79	69.47
" " spring (40)	9.36	12.92	2.15	1.72	1.86	67.98

CHAPTER XXX

Maize (Indian corn)

391. Structure of the Kernel.—Corn has somewhat the same general structure as wheat. The seed coat, however, is composed of two instead of three layers (see Fig. 89). Within the seed coat or hull (1) there is a hard aleurone layer (2) which is thicker at the sides than at the crown. The floury portion (4) which is usually hard and flinty, makes up the larger part of the kernel while the germ (3) constitutes about 10 per cent. of the weight. The proportional amounts of germ, floury portion, and aleurone layer, differ with individual samples. The hulls make up about 5.5 to 6 per cent. of the kernel, while about 85 per cent. is present in the floury portion and aleurone layer. In the milling of corn, as in the milling of wheat, a mechanical separation of the different parts is effected.

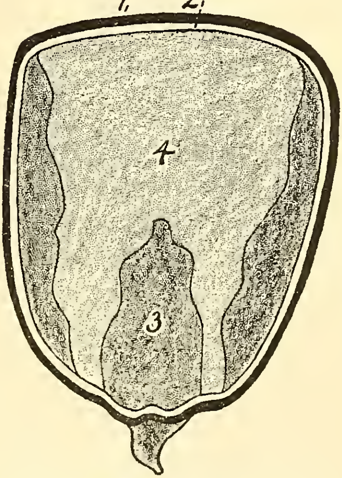

Fig. 89.—Structure of corn kernel: 1, Seed coat; 2, aleurone layer; 3, germ; 4, floury portion (adapted from N. J. Expt. Station Bull.).

392. Composition of Corn.—Corn is fairly constant in composition. As the result of a large number of analyses made by the Department of Agriculture, the following conclusion is drawn: "A study of all the analyses which have been made reveals the fact that maize is one of the most unvariable of the cereals, maintaining under the most different climatic conditions, a most remarkable uniformity of composition, varying chiefly in the size, color, and general physical characteristics of its kernels rather than in their composition."

From the figures given at the close of the next chapter it will be observed that corn contains a much larger amount of fat than wheat, also a somewhat smaller amount of protein; the nitrogen-free extract, which is mainly starch, is about the same in amount in both. Investigations at the Illinois Experiment Station show that all of the kernels upon the same ear are fairly constant in composition, although the kernels on the tip of the ear have a tendency to contain slightly less protein than those either in the middle or at the base; the differences in both protein and carbohydrates in a few extreme cases was about 1 per cent. The composition of the kernel is slightly influenced also by the stage of maturity. If, for any reason, corn fails to reach full maturity, there is usually a somewhat larger amount of protein and smaller amount of carbohydrates in the dry matter.

393. **Proteids of Corn.**—The proteids of corn are quite different in character from those of wheat. Small amounts of albumin and globulin are present but the larger portion of the corn proteids is in insoluble forms called zeins, one of which is soluble and the other insol-

uble in alcohol. The zeins differ in both physical and chemical composition from wheat gliadin. The corn proteids contain about 1 part nitrogen to every 6.23 parts proteid material, while in wheat there is about 1 part nitrogen to 5.7 of proteids.

394. Nitrogenous and Non-Nitrogenous Corn.—The germ and aleurone layers are more nitrogenous in character than the interior or floury portion of the kernel. Since the proportion of germ and aleurone in corn, as in wheat, varies with individual samples, the nitrogenous matter, being greater in these parts, also varies. Taking advantage of this knowledge, it is possible, by mechanical means, to distinguish corn samples of high from those of low protein content. Hopkins, of the Illinois Experiment Station, was the first to direct attention to this fact (Bulletin 55, Illinois Expt. Station).

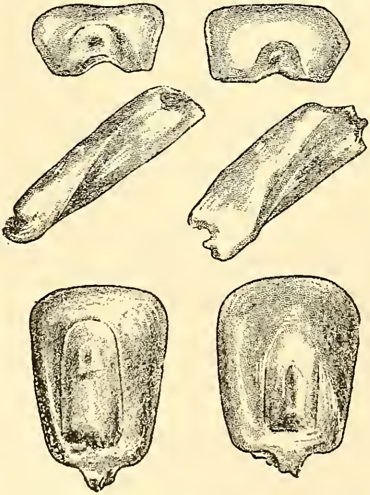

Fig. 90.—Nitrogenous and non-nitrogenous corn: 1, Corn with 14.92 per cent. protein; 2, corn with 7.76 per cent. protein.

"By making cross sections and longitudinal sections of several kernels from an ear of corn, one can judge, with a very satisfactory degree of accuracy, whether the corn is rich or poor in protein. The illustration (Fig. 90) here shown was made from a photograph taken of the corn kernels and sections with a magnification of three diameters. At the left are two sections and a whole kernel from corn containing 14.92 per cent. of protein. The sections and kernel at the right are from corn containing 7.76 per cent. of protein. About one-fourth of the kernel was cut off from the tip end in making the cross sections. In the longitudinal sections the tip end of the kernel points upward to the right. It will be seen that in the cross sections the white starchy layer nearly disappears in the high-protein corn, but becomes very prominent in the low-protein corn. In the longitudinal sections this difference is also apparent, the white starch in the high-protein corn being confined almost entirely to the crown end of the kernel, while in the low-protein corn it extends into the tip end in considerable amount. The germ in the high-protein corn is somewhat larger. This is also indicated by the depressions in the whole kernels.''

Exceptions are, however, occasionally observed in the relation of the form to the protein content of corn, but in making comparisons in the manner indicated, the few errors which are liable to occur are in assigning too low rather than too high a protein value to the sample. In the selection of seed corn a knowledge of the characteristic of the kernels as nitrogenous or non-nitrogenous will be found of value.

Experiment 72.—Select, from a sample of corn, kernels of high- and kernels of low-protein content. Make longitudinal and cross sections of some of the kernels, and note the proportion of germ, aleurone, and floury parts in each. Make a drawing of a representative kernel of each kind of corn. Observe how your rating of the corn compares with the chemical analysis. Determine the weight per bushel and assign a grade to the sample.

395. Varieties of Corn.—The numerous analyses, which have been made of the different varieties of corn as dent or flint, do not show any wide variations in composition when they are grown under similar conditions. The main differences are in the amount of coloring-matter and in the physical characteristics rather than in chemical composition. Yellow corn contains no more nutrients than white corn ; there is coloring-matter present in one and not in the other. Sweet corn contains more sucrose than other varieties but otherwise it has about the same general composition as the dent and flint varieties.

396. Grading of Corn.—Corn is graded entirely upon the basis of its physical properties and soundness rather than on the basis of chemical composition. The rules governing the grading of corn adopted by the Minnesota Railroad and Warehouse Commission in 1902 are as follows :

No. 1 yellow corn shall be sound, yellow, dry, plump, and well cleaned.

No. 2 yellow corn shall be three-fourths yellow, dry, reasonably clean, but not plump enough for No. 1.

No. 3 yellow corn shall be three-fourths yellow, reasonably dry, reasonably clean, but not sufficiently sound for No. 2.

No. 1 white corn shall be sound, dry, plump, and well cleaned.

No. 2 white corn shall be seven-eighths white, dry and reasonably clean, but not plump enough for No. 1.

No. 3 white corn shall be seven-eighths white, reasonably dry and reasonably clean, but not sufficiently sound for No. 2.

No. 1 corn shall be mixed corn of choice quality, sound, dry, and well cleaned.

No. 2 corn shall be mixed corn, dry, reasonably clean, but not good enough for No. 1.

No. 3 corn shall be mixed corn, reasonably dry and reasonably clean, but not sufficiently sound for No. 2.

No. 4 corn shall include all corn not wet and not in heating condition that is unfit to grade No. 3.

No grade corn: All corn that is in a heating condition, too musty or too damp to be safe for warehousing, or that is badly damaged, exceedingly dirty, shall be classed as no grade.

(These rules are subject to change from year to year.)

397. Corn Products. — When the entire kernel is ground, coarse cornmeal is the product. When a part of the corn bran is removed, fine cornmeal is obtained. When the bran and germ are removed and the interior portion of the kernel is reduced as in flour-making, the product is corn flour. By mechanical means, as in the manufacture of starch, the proteid matter can be removed. Cornstarch is sold either as a commercial product, or is used in the preparation of glucose (see Experiment 49). The germ, bran and glutinous matter are by-products which form the basis of a number of commercial feeds. The larger portion of the fat or oil of corn is present in the germ and is recovered as corn oil. A number of other products are also obtained from corn.

398. Corn as a Food.—Corn is extensively used both as human and animal food. Its proteids, however, do not render it as valuable for bread-making purposes as wheat, and on this account, in some countries, it is not as generally used for human food. It is, however, one of the cheapest foods that can be procured, and the prejudice against its use as human food because of its being fed to animals is gradually being overcome. Its value as animal food is too well known to require further discussion.

CHAPTER XXXI

Oats, Barley, Rye, Buckwheat, Rice, and Miscellaneous Seeds

399. Structure of the Oat Kernel.—Oats are composed of two parts, the kernel and the hull. The hulls have the same general composition as straw, and make up about 30 per cent. of the weight. The different parts of the oat kernal are: (1) Seed pod, (2) aleurone layer, (3) germ, and (4) floury portion. The weight per bushel of oats depends largely upon the amount of hulls; in some samples these make up 25 per cent., and in others 35 per cent. of the weight.

400. Composition of Oats.—When the hulls are included, oats have a larger amount of fiber and ash than any other cereal. The per cent. of fat is higher than in wheat, barley or rye, and as high as in corn. Hulled oats have about the same general composition as wheat, with a tendency to a higher protein content. They are also characterized by a high per cent. of fat. Variations in the composition of oats are, to a limited extent, noticeable. The ratio of hull to kernel influences the composition more than any other factor. There is not a great difference in the chemical composition of heavy- and light-weight oats. Experiments at the Maine Experiment Station show that the differences are mainly in the amount of nutrients in a given volume of the grain, as a bushel, rather than in percentage composition. This emphasizes the importance of feeding oats by weight rather than by measure.

401. **Oats as Human and Animal Food.**—Oats are used more extensively as an animal food than as human food. When the hulls are removed and the oats are prepared as human food, they have a high value because of the large amount of available protein, fat and other nutrients which they contain. As an animal food oats are especially well adapted for the feeding of horses, because of their mechanical condition and the comparatively large amount of available nutrients. Experiments at the Wisconsin Experiment Station show that when fed to dairy animals under similar conditions, oats produce 10 per cent. more milk and butter fat than the same weight of bran.

402. **Barley** is used largely for brewing and for animal-feeding purposes rather than as a human food. There is less fat, fiber, and ash than in oats, but more protein and carbohydrates. Barley contains less protein than wheat. For brewing purposes, perfectly sound and fully matured barley is necessary, while that which has been slightly damaged in any way, as by rain, frost or hot winds, is not suitable for this purpose. Such barley, however, can be used for feeding purposes and is frequently the cheapest grain that can be fed by western farmers. Barley is suitable for the feeding of all kinds of farm animals. The hulless varieties contain less fiber and more protein and available carbohydrates. A study of the proteids of barley shows that there is about 1 part of nitrogen to

every 5.7 parts of protein, which is about the same in amount as is found in wheat proteids.

403. **Rye.**—Rye contains proteids similar to wheat, rendering it suitable for bread-making purposes. However, rye is more extensively used in this country for the manufacture of alcoholic beverages than for bread. Rye resembles wheat in chemical composition more than any other cereal, although when grown under similar conditions it contains somewhat less protein than wheat. In the feeding of farm animals, rye must be used with more caution than wheat. If used in a dairy ration in too large amounts, it is believed to have a tendency to produce a slightly inferior quality of milk and butter, but when fed in small amounts no difficulty is experienced. In a mixed ration, rye has been found equal to barley and other cereals for meat production.

404. **Rice.**—Rice is characterized by a low-protein and fat content, and a high per cent of carbohydrates. It is not used to any extent for the feeding of stock, although a number of its by-products are employed for this purpose.

405. **Buckwheat.**—The entire kernel contains quite an appreciable amount of fiber, which is removed in the preparation of buckwheat flour. The amount of protein is somewhat less than in wheat and other cereals. Buckwheat is not extensively used for the feeding of animals, although some of its by-products are valuable for this purpose.

406. **Flax** is a type of oil seed, small in size but with a

large amount of nutrients in the form of fat. Average flax contains about 38 per cent. of fat which is largely removed in the manufacture of linseed oil. A bushel of flax will yield about 19 pounds of oil and 40 pounds of oil cake. Flax is too concentrated and usually too valuable a market crop to be used for animal-feeding purposes. Should the price warrant, it can be used, but it should be combined with other grains, although 8 pounds a day have been fed in a dairy ration without apparent ill results. Unripe and immature flaxseed are often used for feeding purposes. Other oil seeds, as cotton seed and rape, are valuable for the oil which they contain, and the oil cake which is used for feeding purposes.

407. **Millet Seed** has somewhat the same general composition as oats. When fed, however, it should be ground and combined with other grains.

408. **Peas and Beans.**—Peas and beans, as well as other leguminous seeds, are characterized by containing large amounts of protein and variable amounts of fat. Peas and beans are alike valuable as human and animal food. When used as animal food, they should form a part of a grain ration. They are particularly valuable for pork production as well as for meat and milk, but their high price usually prevents their extensive use in animal-feeding. When they can be produced cheaply and abundantly, they are among the most valuable foods that can be used. The proteid of leguminous seeds is largely in the form of legumin, a casein-like body.

409. **Grading of Grains.**—Oats, barley, rye and flax

are all graded commercially on the basis of their physical properties, as weight per bushel, maturity, amount of foreign weed seed, and any fungus disease, or injury caused by rust or excessive heat. The rules adopted by the Minnesota Railroad and Warehouse Commission in 1902, for the grading of barley and rye, are as follows:

OATS

No. 1 white oats shall be white, sound, clean, and free from other grain.

No. 2 white oats shall be seven-eighths white, sweet, reasonably clean and reasonably free from other grain.

No. 3 white oats shall be seven-eighths white, but not sufficiently sound and clean for No. 2.

No. 4 white oats shall be seven-eighths white, but not sufficiently sound and clean for No. 3.

No. 1 oats shall be mixed oats, sound, clean, and reasonably free from other grain.

No. 2 oats shall be sweet, reasonably clean, and reasonably free from other grain.

No. 3 oats shall be all oats that are merchantable and warehousable, reasonably clean, not fit for higher grades.

No grade oats: All oats that are in a heating condition, too musty or too damp to be safe for warehousing, or that are badly damaged, and exceedingly dirty, shall be clased as no grade.

RYE

No. 1 rye shall be sound, plump, and well cleaned.

No. 2 rye shall be sound, reasonably clean, and reasonably free from other grain.

No. 3 rye, all rye slightly damaged, slightly musty, or from any other cause unfit for No. 2 shall be graded as No. 3.

No grade rye: All rye that is in a heating condition, too musty or too damp to be safe for warehousing, or that is badly damaged and exceedingly dirty, shall be classed as no grade.

BARLEY

No. 1 barley shall be plump, bright, clean, and free from other grain.

No. 2 barley shall be sound, of healthy color, not plump enough for No. 1, reasonably clean and reasonably free from other grain.

No. 3 barley shall include all slightly shrunken and otherwise slightly damaged barley, not good enough for No. 2.

No. 4 barley shall include all barley fit for malting purposes, not good enough for No 3.

No. 5 barley shall include all barley which is badly damaged or for any cause unfit for malting purposes, except that barley which has been chemically treated shall not be graded at all.

No grade barley: All barley that is in a heating condition, too musty or too damp to be safe for warehousing, or that is badly damaged and exceedingly dirty, shall be classed as no grade barley.

FLAXSEED

No. 1 northwestern flaxseed shall be mature, sound, dry, and sweet. It shall be northern grown. The maximum quantity of field, stack, storage, or other damaged seed intermixed shall not exceed 12.5 per cent. The minimum weight shall be 51 pounds to the measured bushel of commercially pure seed.

No. 1 flaxseed shall be nothern grown, sound, dry, and free from mustiness, and carrying not more than 25 per cent. of immature or field, stack, storage, or other damaged flaxseed, and weighing not less than 50 pounds to the measured bushel of commercially pure seed.

Rejected flaxseed: That which is bin-burnt, immature, field-damaged or musty, and yet not to degree to be unfit for storage, and having a test weight of not less than 47 pounds to the measured bushel of commercially pure seed shall be rejected.

No grade flaxseed: That which is damp, warm, moldy, very musty, or otherwise unfit for storage, or having a weight of less than 47 pounds to the measured bushel of commercially pure seed shall be no grade.

(These rules are subject to change from year to year.)

COMPOSITION OF GRAINS AND SEEDS.
(From Jenkins and Winton.)

	Water. Per cent.	Crude protein. Per cent.	Ether extract. Per cent.	Nitrogen-free extract. Per cent.	Crude fiber. Per cent.	Ash.
Corn, dent	10.6	10.3	5.0	70.4	2.2	1.5
" " (max.)	19.4	12.8	7.5	75.7	4.8	2.6
" " (min.)	6.2	7.5	3.1	65.4	0.9	1.0
" flint	11.3	10.5	5.0	70.1	1.7	1.4
" sweet	8.8	11.6	8.1	66.8	2.8	1.9
Oats	11.0	11.8	5.0	59.7	9.5	3.0
Barley	10.9	12.4	1.8	69.8	2.7	2.4
Rye	11.6	10.6	1.7	72.5	1.7	1.9
Rice	12.4	7.4	0.4	79.2	0.2	0.4
Buckwheat	10.9	10.5	5.4	69.6	2.1	1.5
Peas[1]	10.1	21.6	1.0	58.2	5.7	3.4
Flaxseed[1]	5.1	27.5	38.6	17.9	7.4	3.5
Millet seed[1]	12.5	10.6	3.9	61.1	8.1	3.8
Navy beans	12.4	22.2	1.4	53.1	7.2	3.7

[1] Minnesota analyses.

CHAPTER XXXII

Mill and By-Products

410. **Sources.**—In the milling of wheat, the preparation of cereal foods, the malting of grains, the extracting of oil from seeds and the manufacture of starch and glucose, various by-products are obtained which are used for the feeding of animals.

411. **Wheat By-Products.**—In the milling of wheat, about 72 per cent. of the grain is returned as straight and patent grade flours, 2.5 to 3 per cent. as low-grade and red-dog, and 25 per cent. as wheat-offal—bran, shorts and germ. The separation of the wheat kernel into these various products is a mechanical operation effected by rolls for the reduction of the grain, and sieves and bolting-cloths for the separation of the various products. The standard grades of flour and the percentage amounts of each recovered in milling are approximately as follows:

	Per cent. of cleaned wheat recovered.
1. First patent	56.0
2. Second patent	60.8
3. Straight or standard patent	72.1
4. First clear or first bakers	11.8
5. Second clear or low-grade	0.5
6. Red-dog	1.9
7. Shorts middlings	11.6
8. Bran	13.4

(Straight grade flour is composed of first and second patents and first clear grade.)

412. **Wheat Bran** is composed mainly of the outer layers of the wheat kernel separated in the process of milling (see Fig. 88). Along with the outer layers, some of the floury portion and aleurone cells are removed, and find their way into the bran and fine bran or shorts. Wheat bran varies in chemical composition and feeding value according to the composition and character of the wheat used and the process of milling employed. Wheat bran may contain as low as 14 and as high as 18 per cent. of crude protein ; average bran contains about 16 per cent. Two samples of bran may contain the same percentage amount of protein and not have the same feeding value. For example, one wheat containing 13 per cent. protein can be exhaustively milled and yield a bran of 16 per cent. protein while another wheat with 14 per cent. imperfectly milled may yield a bran with 16 per cent. protein. While both brans contain the same amount of crude protein, 16 per cent., the second sample would contain the larger amount of available non-nitrogenous nutrients and with the same per cent. of crude protein would produce better results in feeding than the first sample. The lower grades of flour are frequently left in the bran, imparting a high nutritive value. Spring wheat bran usually contains more protein than winter wheat bran. This is due largely to the more nitrogenous character of the spring wheat. Pure bran should be free from weed seeds and all foreign matter. Bran occupies a high position among animal food-stuffs. It is bulky in nature and can be fed in comparatively large amounts without injury to animals. Director Henry in "Feeds and Feed-

ing'' states: ''Next to corn, wheat bran is the great cow feed of this country. Rich in ash and protein, carrying a fair amount of starchy matter, its light chaffy character renders it the natural complement of heavy cornmeal. Though its nutritive constituents approximate those of cottonseed meal, it mixes well with that feed, causing it to lie more lightly in the stomach.

''The large amount of mineral matter in bran is another factor of much importance in milk production. In milk there is much mineral matter, placed there for the framework of the calf, and bran supplies this more abundantly than most feeding-stuffs.

''Middlings, like bran, are extensively fed to dairy cows. Being themselves heavy in character, they do not mix well with heavy feeds like cottonseed-meal and cornmeal. Dairymen will find middlings much relished by cows and yielding satisfactory returns. Bran and middlings are conceded by all who have fed them to favorably affect the flow of milk. Cows may be fed as much as 6 to 8 pounds of bran daily and from 4 to 6 pounds of middlings. Bran was at first regarded with favor only by dairymen. Gradually the steer feeder is learning its value in connection with other grain in the feed box. Because of its bulky character and its cooling, slightly laxative properties, bran is a most excellent diluent for cornmeal, cottonseed-meal and other heavy food substances. Where it can be obtained at a reasonable price, the stockman will find much satisfaction in mixing one-third its weight of bran with cornmeal.''

In commenting upon the feeding value of bran, Jordan, in the "Feeding of Animals," states: "No commercial feeding-stuffs are regarded with greater favor, or are more widely and largely purchased by American feeders than the by-products from milling wheat. Wheat bran and middlings are cattle foods of standard excellence, whether we consider composition, palatableness or their relation to the quality of dairy products."

413. **Wheat Shorts** consist of those outer portions of the wheat kernel which contain less crude fiber, protein, and ash than the parts which make up the bran. This product is practically the fine bran subjected to more complete pulverization and mixed with some low-grade flour. It is more variable in composition than bran, but for some purposes, as pig-feeding, is more valuable. When the wheat germ is added to the shorts, the product is called middlings or shorts middlings. When used in this connection, the term middlings means an entirely different product from the middlings obtained by the stone process of flour production; such middlings are now reduced and recovered in the patent grades of flour. Shorts middlings are richer in protein and fat than ordinary shorts. When the weed seeds, and the screenings and scourings of the wheat are mixed with the shorts, a product known as shorts feed is obtained. This practice, however, is not generally followed.

414. **Wheat Germ** is exceedingly rich in both protein and fat. About 8 per cent. of the wheat kernel is removed as germ in the process of milling, because if added to the patent flour, it imparts poor keeping qualities and

its proteid is not suitable for bread-making purposes. Wheat germ contains a number of nitrogenous and phosphorized compounds which can be extracted along with the oil, and which are laxative in character. On this account, pure wheat germ cannot be fed alone or in large amounts in a ration, but when combined with other foods, it is valuable.

415. **Wheat Screenings** are a mixture of various seeds with occasionally the broken and shrunken wheat kernels, and vary in composition and food value with the different kinds of weed seeds present. When fed, they should be finely ground so as to prevent the introduction of foul weeds on the farm. During recent years, mustard seeds have been removed from wheat screenings and sold as a separate product, the oil which they contain being extracted and used commercially.

416. **Linseed Meal.**—When the oil is extracted from flaxseed, linseed cake is obtained which, when ground, forms linseed meal. Pure linseed meal should contain 36 per cent. crude protein. The darker-colored meals are those which contain moist oil. Linseed meal is a concentrated nitrogenous animal food and is valuable for the feeding of all kinds of farm animals. When used, it should be combined with other foods. Linseed meal is occasionally adulterated with flax screenings. Hence, in its purchase, if adulteration is suspected, preference should be given to the nut rather than to the fine ground meal. The cake itself is not adulterated because weed seeds and impurities must be removed in order to produce

a good quality of oil. When the oil is removed from the flaxseed by naphtha and other chemicals, the product is called "new process linseed meal" which differs from pressure process meal by having the oil more thoroughly extracted and by containing a larger amount of crude protein.

417. **Cottonseed Cake and Meal** obtained from cottonseed after the removal of hulls and the extraction of the oil, are concentrated nitrogenous foods. The meal is lemon-yellow in color and is characteristically rich in crude protein and ether extract. It contains somewhat more crude protein than linseed meal. Cottonseed meal is a concentrated nitrogenous food and can be fed, when properly combined with other foods, to sheep and beef and dairy animals. It cannot safely be fed in large amounts nor for a long period to swine. When used in a dairy ration as the principal food, it influences the character of the butter-fat, producing butter with a high melting-point.

418. **Oat Feed** is a product obtained in the manufacture of oatmeal. It is variable in composition and consists of light-weight oats mixed with oat hulls. Oat hulls have about the same composition and feeding value as oat straw and are frequently used for the adulteration of animal foods. In the purchase and use of oat feeds, particular attention should be given to their composition. High-grade oat feed is valuable, but when consisting of any appreciable amount of oat hulls, the food value is proportionally lessened.

419. **Gluten Meal** is a by-product obtained in the manufacture of glucose. The soaked corn is broken open and the germ is liberated and floated off with water. The oil from the germ is extracted and the germ cake sold as a commercial product or used for mixing with other foods. The starch and gluten of the corn are separated by mechanical means. The starch being heavier separates and settles, while the gluten is floated off with water. The gluten product is dried, ground and sold as gluten meal which usually contains about 35 per cent. of protein and 3 per cent. of fat. Gluten feed contains the corn hulls or bran along with the gluten meal. The hulls reduce the proportion of protein. Gluten feed usually contains about 25 per cent. of crude protein but is quite variable in composition.

420. **Malt Sprouts.**—When barley is subjected to the malting process, germination takes place, which results in changing the starch of the grain to maltose. The plantlets or sprouts are removed, dried and sold as malt sprouts. They are nitrogenous in character and contain about 22 per cent. of crude protein, the larger portion of which is present in soluble form. Malt sprouts are valuable for feeding sheep and beef and dairy stock.

421. **Miscellaneous By-Products.**—There are a large number of miscellaneous by-products used for the feeding of animals, as rye bran, buckwheat middlings, palm-nut meal, hominy chops, etc. Their composition and general feeding value can be determined from the table of analyses at the close of the chapter.

422. Inspection of Feeding-Stuffs.—During recent years, many of the states have passed laws regulating the inspection and sale of animal feeding-stuffs. The object of such laws is to prevent adulteration of animal foods by requiring manufacturers and dealers to guarantee the percentage amounts of crude protein and fat. Many of the European countries have had such laws in force for a number of years. It is noticeable that in those countries and states where feeding-stuffs are subjected to inspection, the quality is better than where they are not inspected.

Experiment 73.—Graphic composition of foods. Make a drawing of some human or animal food material and indicate graphically, the percentage amount of the different nutrients. If a hundred millimeter rule is used in the construction of the drawing, each linear millimeter will correspond to 1 per cent. If a food contains 12 per cent. water, 12 millimeters are measured off to represent the water in the material, and so for each class of nutrients, an area corresponding to its percentage amount.

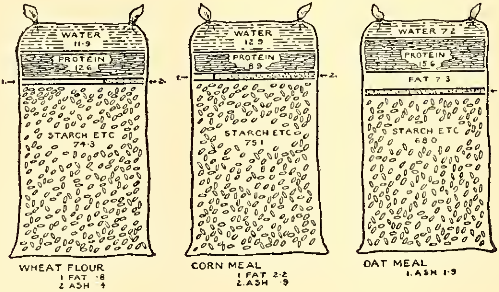
WATER
11·9
PROTEIN
12 6
1.
2.
STARCH ETC
74·3
WHEAT FLOUR
1 FAT ·8
2 ASH ·4
WATER
12 9
PROTEIN
8 9
1.
2.
STARCH ETC
75 1
CORN MEAL
1 FAT 2·2
2. ASH ·9
WATER 7 2
PROTEIN
15 6
FAT 7 3
1
STARCH ETC
68 0
OAT MEAL
1. ASH 1·9

Fig. 91.—Graphic composition of foods.

COMPOSITION OF MILL AND BY-PRODUCTS

	Water. Per cent.	Ash. Per cent.	Protein. Per cent.	Crude fiber. Per cent.	Nitrogen-free ex't. Per cent.	Fat. Per cent.
Linseed meal (old process) .	9.20	5.70	32.90	8.90	35.40	7.90
" " (new process)	10.10	5.80	33.20	9.50	38.40	3.00
Cottonseed-meal	8.20	7.20	42.30	5.60	23.60	13.10
Malt sprouts	10.20	5.70	23.20	10.70	48.50	1.70
Corn and cob meal	15.10	1.50	8.50	6.60	64.80	3.50
Gluten meal	9.60	0.70	29.40	1.60	52.40	6.30
" feed	7.80	1.10	24.00	5.30	51.20	10.60
Oat feed	7.70	3.70	16.00	6.10	59.40	7.10
" hulls	7.30	6.70	3.30	29.70	52.10	1.00
Sugar-beet pulp[1]	88.53	4.85	9.45	22.40	62.62	0.68
Rye bran	11.60	3.60	14.70	3.50	63.80	2.80
Buckwheat middlings	13.20	4.80	28.90	4.10	41.90	7.10
Palm-nut meal	8.30	3.70	14.40	21.40	38.90	13.30
Hominy chops	11.10	2.50	9.80	3.80	64.50	8.30
Apple pomace	76.70	0.50	1.40	3.90	16.20	1.30
Wheat bran, winter	12.30	5.90	16.00	8.10	53.70	4.00
" " spring	11.50	5.40	16.10	8.00	54.50	4.50
" shorts	11.80	4.60	14.90	7.40	56.80	4.50
" screenings	11.60	2.90	12.50	4.90	65.10	3.00
Meat scrap	1.33	8.03	57.69	...	....	32.95
Wheat flour (Minn.)	11.90	0.40	12.60	...	74.30	0.80
Cornmeal	15.10	1.40	9.20	1.90	68.70	3.80
Corn flour	12.57	0.61	7.13	0.87	78.36	1.33
Buckwheat flour	14.60	1.00	6.90	0.30	75.80	1.40
Oatmeal	7.90	2.00	14.70	0.90	67.40	7.10

[1] Dry matter basis.

CHAPTER XXXIII

Roots, Tubers, and Fruits

423. General Composition.—Roots, tubers, and fruits contain a large amount of water and a small amount of dry matter. The dry matter is composed mainly of non-nitrogenous compounds as starch and sugar. These foods all contain small amounts of nitrogenous compounds of which the larger portion is in amide and non-proteid forms. Organic acids in small amounts and essential oils are characteristic features.

424. Potatoes contain about 75 per cent. of water. The dry matter is largely starch. About half of the nitrogen is present as proteids of which the larger portion is in the form of soluble albumin. The amount of fat is small, less than a tenth of 1 per cent. Potatoes contain but little cellulose. Tartaric and other organic acids,

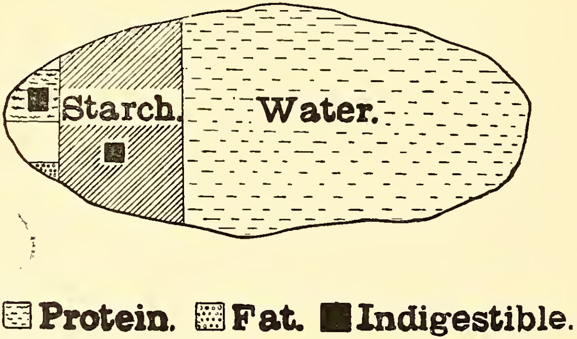

Fig. 92.—Composition of potatoes.

pectose substances, and other compounds are present in small amounts. When potatoes are stored for any length of time and fermentation takes place, a portion of the starch is converted into glucose. In storing them, a low temperature and good ventilation are necessary to prevent fermentation. Potatoes are a concentrated non-nitrogenous food.

425. **Carrots** contain about half as much dry matter as potatoes. There is approximately the same amount of water as in milk, *viz.*, 87 per cent. The 12 per cent. of dry matter is nearly half sugar, 3 per cent. being fruit sugar and 3 per cent. other sugars. Carrots contain 1.20 per cent. of total nitrogenous compounds given as crude protein in tables of analyses, of which 40 per cent. is protein. There is more fat in carrots than in potatoes.

426. **Parsnips** contain more dry matter than carrots and have nearly the same amounts of nitrogenous compounds, fat and fiber, but less sugar and more starch. They have about the same general food value as carrots.

427. **Mangel** wurzels contain more water and less dry matter than carrots. The dry matter, however, is richer in nitrogenous compounds than that of carrots, parsnips, potatoes or beets, which makes the mangels

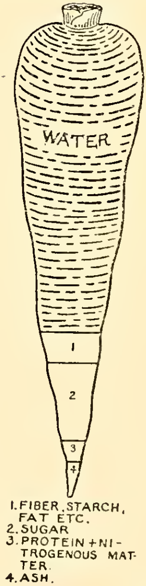

Fig. 93.—Composition of carrots.

a better balanced food. The 10 per cent. of dry matter in mangels is a little more than half starch and contains about 1.40 per cent. of crude protein of which half is protein. Mangels also contain about 1 per cent. each of ash and fiber and a small amount of fat.

428. **Apples** vary in composition with the variety and physical characteristics. They contain from 10 to 16 per cent. solids, of which 75 per cent. is sugar or allied carbohydrates, and about half a per cent. each is fat and protein. Among the organic acids, malic predominates. The flavor and special characteristics depend upon the relative amounts of the different sugars, as sucrose, levulose and dextrose, and the organic acids and essential oils which the apples contain. It is these compounds which give individuality to apples.

429. **Oranges** contain from 10 to 15 per cent. of solid matter, the larger portion (80 per cent.) being sugar. The citric acid content ranges from 1 to 2.5 per cent. in different varieties. The amount of protein, fat and fiber is small. The ash or mineral matter averages about one-half per cent. and is composed mainly of potash and lime with smaller amounts of other compounds. The iron and sulfur content in some kinds of oranges is larger than is ordinarily found in other fruits. In average oranges, the physical composition is as follows: Rind, 20 to 30 per cent.; pulp, 25 to 35 per cent.; and juice, 35 to 50 per cent.

430. **Lemons** differ from oranges in containing larger amounts of citric acid and smaller amounts of sucrose,

levulose and dextrose. The average composition of lemons is as follows:

Physical composition.		Chemical composition.	
	Per cent.		Per cent.
Rind	25 to 35	Solids	10 to 12
Pulp	25 to 35	Sugar	2 to 4
Juice	40 to 55	Citric acid	6 to 9

The ash of the lemon is somewhat similar in composition to the ash of the orange but is present in larger amount.

431. **Strawberries** are characterized by containing a high per cent. of water (90 to 92 per cent.). Sugar and malic acid are the materials present in largest amounts while protein, fat, ash and fiber form but a small part of the composition. Coloring materials and essential oils are also present in small amounts. While strawberries are valuable as a food adjunct, they do not supply any appreciable amount of nutrients. It has been estimated that it would require 13 pounds of strawberries to supply the carbohydrates needed for a daily ration to say nothing of the protein which would require 65 pounds additional. The malic and other acids present are valuable because of their antiseptic properties which, added to the appearance and palatability, make strawberries a valuable food adjunct.

432. **Grapes** vary in composition according to variety. They contain from 15 to 20 per cent. of solid matter. The juice contains from 10 to 15 per cent. or more of sugar in the form of sucrose, levulose and glucose. The tartaric acid, which is found in grapes in larger amount than in other fruits, ranges from 1 to 1.5 per cent. Grapes do not contain any appreciable amount of protein

or fat and while they add some nutrients, as sugar, to a ration, they do not contribute any large amounts. There is some food value but it is not as high as is occasionally claimed for them. Their value, as is the case with other fruits, is in palatability and indirectly aiding in digestion and adding value to other foods.

433. **Olives,** when fully matured and fresh, contain about 15 per cent. of oil. When preserved green, there is considerably less. Olives also contain small amounts of other compounds and essential oils. Pure olive oil is a valuable food, but is frequently adulterated with refined cottonseed and other vegetable oils. Olive oil is slightly laxative in character and assists mechanically in the digestion of foods by preventing compaction of feces in the intestines.

434. **Dried Fruits.**—In preparation for the market, many fruits are preserved by drying. The dried fruit has a somewhat different composition from the fresh fruit because of chemical changes which take place during the drying process and the slight loss of volatile and essential oils. Dried fruits, when free from preservative agents, are valuable, and can be used to advantage if fresh fruits are not obtainable.

435. **Miscellaneous Fruits.**—Since the list of fruits that could be discussed is so large, only a few examples have been considered. For additional information upon the subject, or for data upon fruits not given, the student is referred to the bulletins of the California Experiment Station.

436. Food Value.—When judged only on the basis of the nutrients present, many vegetables and fruits would be assigned a low place in the list of foods as they contain only comparatively small amounts. Most fruits are used in the dietary, not so much with the view of supplying nutrients as for other purposes. The organic acids, essential oils, and soluble mineral compounds, together with the digestible form in which the nutrients are present are the factors which give fruits their unique value. The organic acids and essential oils impart palatability and assist functionally in the digestive process. Some fruits, as figs and prunes, contain chemical compounds which are laxative in character. In the human ration, fresh fruits are as essential and occupy the same position as do roots and vegetables in animal rations.

CHAPTER XXXIV

Fermentation

437. Insoluble Ferments.—Fermentation is a chemical change produced by a class of bodies called ferments. Insoluble or organized ferments are single-celled, microscopic plants which have a definite structure. Many of them are bacteria while others are low forms of plant life. Nearly all secrete definite chemical products capable of producing fermentation. The insoluble or organized ferments are composed mainly of nitrogenous compounds but also contain non-nitrogenous and mineral matter. Some, as the tubercular organism, contain cellulose.

438. Soluble Ferments or Enzymes.—Enzymes are organic compounds, secreted by cells, and have the property of producing chemical changes. They are also called soluble ferments, chemical ferments, and diastases. There are a great many different kinds of soluble ferments some of which, as diastase and maltase, are capable of acting upon carbohydrates, while others, as pepsin and pancreatin, act upon proteid bodies. Enzymes produce chemical change without entering into the composition of the substance or giving up any of their own material to the reacting compounds. A small amount of diastase will change a large amount of starch to soluble forms without losing its power of action. The enzymes are all soluble in water and are precipitated with strong alcohol. Their action is not generally retarded by antiseptics and chemicals which are capable of destroying organized ferments. When seeds are soaked in water, the diastase and proteose enzymes are extracted and if precipitated with alcohol and recovered, they appear as a light gray powder. An organized ferment is a low form of plant, while a soluble ferment is a chemical compound.

439. **Aerobic and Anaerobic Ferments.**—Ferments which require oxygen for their existence are aerobic while those which are capable of working in the absence of oxygen are anaerobic. The aerobic ferments produce carbon dioxid, water, ammonia and hydrogen sulfid as final products, while the anaerobic ferments usually produce intermediate products as organic acids.

440. **Conditions Necessary for Fermentation.**—The conditions necessary for fermentation are: (1) Moisture, (2) favorable temperature, (3) a ferment body, and (4) a fermentable substance. Moisture is necessary in order that the chemical changes may take place. During fermentation water frequently enters into the chemical reaction, as in hydration changes, and is also necessary as a medium of exchange for the chemical products during the reaction. The most favorable temperatures for fermentation are between 15° and 60° C. Below zero and above the boiling-point of water, ferments are inactive. Some ferments require a different temperature for activity than others. A ferment body is always necessary in order to start the fermentation change, and in the absence of a ferment either organized or unorganized, no fermentation can take place. A fermentable substance, with the right kind of ferment to act upon it, is also req-

uisite, as a ferment which acts upon one class of bodies is incapable, unaided, of acting upon others ; for example, the peptic ferment is incapable of changing starch to soluble forms. When a substance is freed from all ferments and is protected from outside sources of contamination, it is in a sterile condition. Many forms of fermentation are produced by the spores of organized ferments gaining access to a material along with dust particles carried in the air. In the preservation of food, a knowledge of the conditions requisite for fermentation is made use of. The products formed by ferments are numerous, as there are ferment bodies capable of acting upon all forms of organic matter. Some of the ferments assist in the digestion of food and in the preparation of food products, while others take an important part in every-day life affairs, and in agriculture as in the liberation of plant food. The growth of plants, the preparation of foods, and their digestion, and the manufacture of food products all depend largely upon fermentation.

441. Soil Ferments.—In the growth of plants, ferments take an important part, both in the preparation of the plant food and in the chemical changes which take place within the plant. Disintegration of the mineral food of the soil is assisted by ferment action. The nitrogenous food of the plant is all prepared in the soil by ferments. The subject of soil ferments is briefly considered in the "Chemistry of Soils and Fertilizers."

442. Ferments in Seeds.—In the seeds of plants, particularly matured grains, there are a number of ferments which take an important part in the process of germination. These ferments change the insoluble nitrogenous and non-nitrogenous compounds to soluble forms, which are utilized by the young plant as food. If a seed were deprived of all of its soluble ferments, it would fail to germinate.

Experiment 74.—Action of malt on starch. Crush in a mortar twenty malted barley kernels, transfer to a test-tube, and add 15 cc. water. After twenty-four hours, filter off the solution, and add it to a flask containing 2 grams of flour and 100 cc. water. Place the flask in the desk for twenty-four hours; then filter off the solution and test a portion for starch with iodin, as in Experiment 45. Test another portion for glucose with Fehling's solution, as in Experiment 48.

Questions. (1) What is malted barley? (2) What did the water extract from the barley contain? (3) What effect did this extract have upon the flour? (4) What did the tests with iodin and Fehling's solution show? (5) Would flour treated with water instead of malt extract give the same result?

443. Ferments in Bread-Making.—The yeast plant employed in bread-making secretes a number of soluble ferments which produce the desired chemical changes. The diastase ferment changes the starch to soluble forms, the alcoholic ferment produces alcohol and carbon dioxid gas, which expand the dough and make the bread light, and acid ferments produce acids, which combine with the gluten proteids and modify their character. In short, bread-making is simply a series of chemical changes induced by soluble ferments.

Experiment 75.—Alcoholic fermentation. Weigh 10 grams of flour into a flask, add 50 cc. water and a small piece of yeast (one-tenth of a cake). Connect the flask by means of a delivery tube with the Woulff bottle containing enough clear lime water to cover the end of the tube. Place the flask on a warm sand-bath, below 85° F., for half an hour. Observe the bubbles of gas given off and the precipitate formed in the lime water. Do not overheat the sand-bath.

Questions. (1) What is yeast and what does it contain? (2) What caused the gas to be given off? (3) From what was the gas formed? (4) Write the reaction with $Ca(OH)_2$. (5) What becomes of the alcohol?

444. **Ferment Action and Food Digestion.**—The digestion of food is carried on largely by the action of soluble ferments. The digestive tract secretes a number of these, which act upon the insoluble nutrients and change them to soluble forms. In fact, the digestion of food is dependent upon the action of the different ferments in the digestive tract, as ptyalin in the saliva, pepsin in the stomach, pancreatin in the duodenum, and diastase and other ferments in the intestines.

445. **Ferments and Food Preservation.**—Preservation of food is dependent upon prevention of ferment action. The low temperature of cold storage is unfavorable to the development of ferments. Sterilization is likewise unfavorable. By means of heat, cold storage, chemicals, and protection from the spores in the air, perishable food products are preserved. Some ferments, however, are not destroyed either by high or low temperatures.

446. **Ferments in Butter- and Cheese-Making.**—The process of butter- and cheese-making is carried on with the aid of ferments. Milk itself contains enzymes or soluble ferments and, to a limited extent, is itself capable of acting as a digestive fluid. The ripening of cream is

the result of the action of the lactic acid ferment which changes the lactose (milk-sugar) into lactic acid. In cheese-making, the rennet used for coagulating the milk contains a number of ferments which take an important part in the process. The flavor and odor of butter as well as of cheese are the results of ferment action. In butter- and cheese-making, it is the object to control the action of the desirable ferments and to prevent the undesirable ones from developing. Ropy milk, red spots in cheese, and floating curds in cheese-making, are all caused by fermentation. Butyric acid, one of the products found in foul milk and butter, is caused by the butyric acid ferment. Milk is exceedingly susceptible to the action of ferments.

Experiment 76.—Lactic fermentation. Place 5 grams milk-sugar, 100 cc. water, 5 cc. skim milk, and two or three crystals of sodium phosphate in a flask. Leave the flask uncorked in the desk for twenty-four hours. Then add a few drops of phenolphthalein indicator, and determine the amount of lactic acid. 1 cc. alkali = 0.009 gram acid.

Questions. (1) Why was milk used in this experiment? (2) What was produced from the milk-sugar? (3) Why was sodium phosphate used? (4) How much acid was produced?

447. Disease-Producing Organisms.—Many diseases are caused by the action of micro-organisms. The disease-producing organisms or bacteria invade the body and rapidly multiply, living upon the fluids and tissues of the body and producing poisonous products. Typhoid fever, smallpox, diphtheria, tuberculosis, cholera, and many other diseases are caused by specific bacteria. The products produced by the action of the organism are poisonous, and death is often caused by these toxic bodies. Modern methods of sanitation are based upon the destruction of disease-producing organisms.

448. Beneficial Organisms.—While many diseases are caused by micro-organisms, not all micro-organisms or bacteria are injurious. In nearly all foods, there are large numbers of bacteria which are of a harmless nature. Some are valuable and beneficial to man, particularly those which assist in plant nutrition and in the preparation and digestion of foods.

CHAPTER XXXV

Chemistry of Digestion and Nutrition

449. Digestion, a Biochemical Process.—In the digestion of food, the enzymes or soluble ferments take an important part. Although digestion is not well understood it is known to be largely a chemical process brought about by ferment action, and hence is called a biochemical process. The cells in the different parts of the digestive tract secrete chemical products which produce chemical changes in the food, rendering it soluble so that the various nutrients can be absorbed and used by the body. Any compound which is capable of undergoing digestion and being utilized for food purposes is called a nutrient. The value of any food depends upon the kinds and amounts of nutrients present. During the process of digestion, a complex series of chemical changes take place, and as a result of this process and the assimilation of the food by the body, heat and energy are produced.

450. Digestion Experiments.—The digestibility of a food is determined by a digestion experiment. The percentage amount of a nutrient which is digested is called the coefficient of digestibility. Not all of the nutrients in foods are alike digestible. In clover hay, for example, 65 per cent. of the organic matter is digested, while only 30 per cent. of the crude fiber and 70 per cent. of the nitrogen free extract compounds are digested. Each compound has its own digestion coefficient. In order to determine the digestibility of a food, an animal is fed, for a number of days, a weighed amount of food which is analyzed. All of the feces or solid excrements produced during the experimental period are collected, weighed and analyzed. After undergoing the process of digestion, the undigested portions of the food along with a small amount of digested products are excreted as feces, while the liquid wastes of the body contain the products of the digested food. From the weight of the food consumed and its analysis, the amount of each class of nutrients consumed is determined. From the dry matter of the feces, the undigested nutrients are likewise determined. The undigested nutrients subtracted from the total nutrients in the food consumed give the amounts digested which are calculated on a percentage basis. In the case of clover hay, an animal may consume 28 pounds per day containing 12 per cent. protein; this is equivalent to 3.36 pounds of protein ($28 \times 0.12 = 3.36$). An account is opened with the animal in which a charge for 3.3 pounds of protein is entered. From the 28 pounds of food, 40 pounds of feces or excrements are obtained, as a large amount of water is added during the process of digestion. The feces which are composed largely of the indigestible portions of the food are analyzed and found to contain 20 per cent. of dry matter; this is equivalent to 8 pounds of indigestible matter yielded by the 28 pounds of clover ($40 \times 0.20 = 8$). The dry matter is analyzed and found to contain 15 per cent. of protein; this is equivalent to 1.2 pounds of protein ($8 \times 0.15 = 1.2$). The animal was charged with 3.36 pounds of total protein; 1.2 pounds are found to be indigestible, leaving a balance of 2.16 pounds of digestible protein, equivalent to 64 per cent. of the total. ($2.16 \div 3.36 \times 100 = 64$). 64 is the digestion coefficient of the crude protein in this clover hay. In like manner, the digestion coefficients of all of the nutrients are determined.

Example.—From the following figures, calculate the digestion coefficients of the organic matter, ether extract, crude fiber and nitrogen-free extract of the clover hay. The figures for the composition of clover hay are on the basis of the food as fed, while those for the feces are on the basis of the dry matter.

	Composition of clover. Hay as fed.	Composition of feces (Dry matter.)
Water	10.00	....
Ash	6.90	9.50
Ether extract	3.10	2.10
Crude protein	12.00	15.00
Crude fiber	26.00	30.00
Nitrogen-free extract	42.00	43.40

451. Caloric Value of Foods.—During the process of digestion, heat is produced in proportion to the calories contained in the food and the nutrients digested. By the caloric value of a food is meant the amount of heat measured in calories which the food yields. A calorie is the amount of heat required to raise 1 kilogram of water 1° C. or 1 pound of water about 4° F. The caloric value of a food is determined by means of the calorimeter (Fig. 94). The calorimeter consists of a steel bomb that is placed in a metal cylinder (Q) (Fig. 95). The bomb is surrounded by water as indicated in the illustration, and the cylinder containing the bomb and water is placed within a double-walled fiber receptacle (T and U). The bomb itself consists of three parts: The cylinder, which is lined with platinum, the cover, and a collar to hold the cover in place and tightly seal the bomb. These three parts of the apparatus are shown in Fig. 96.

The principle involved in determining the caloric value of a food is simple. A weighed amount of the substance is burned in the calorimeter and the rise in temperature of the water that surrounds the bomb is noted. The combustion is carried on in oxygen so as to be complete, and all means possible are employed to secure accuracy of results. The substance to be burned, if it is a material like flour, is made into a pellet by

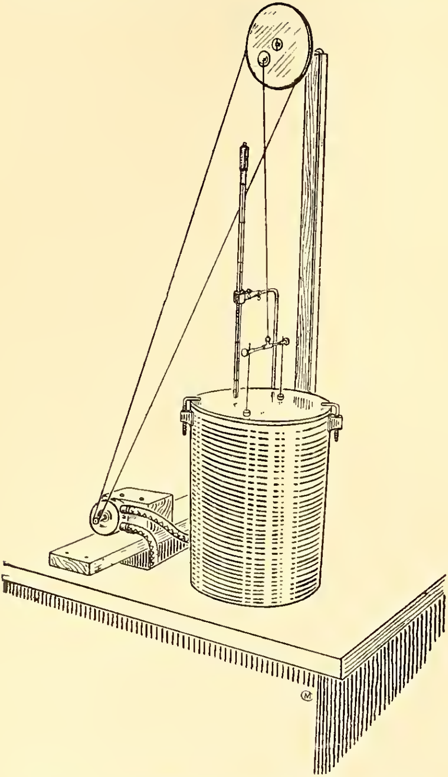

Fig. 94.—Bomb calorimeter used for determining the caloric or heat-producing value of foods.

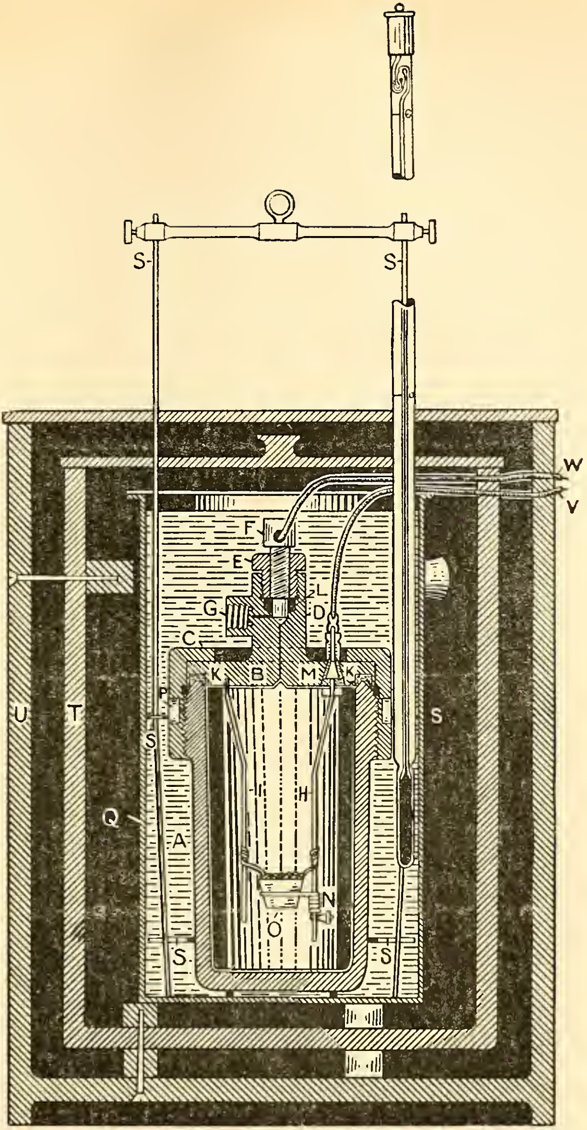
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Fig. 95.—Bomb calorimeter, showing interior structure and working parts.
Atwater, Conn. (Storrs) Agr. Expt. Station, annual report, 1897.

means of a press. The object of making the material into a pellet is that it may form a compact mass and burn evenly and not be scattered about in the calorimeter cylinder and be only partially burned. The pellet is placed in the small platinum crucible O (Fig. 95). This crucible is supported by platinum wires attached to the cover of the calorimeter. Above the crucible a small coil of fine iron wire is stretched from the platinum wires. The cover is screwed tightly upon the cylinder of the bomb and oxygen is admitted from an oxygen tank under pressure through valve G of the cover until a pressure of twenty atmospheres is secured, when the valve is securely closed. The bomb with the substance to be burned, and charged with oxygen is placed in the metal cylinder Q, which contains a definite amount of water, the temperature of which is carefully determined by means of a thermometer that reads to 0.005° C. The water is kept at an even temperature by means of the metal stirrer SS, operated by a water motor. A connection is made with a storage battery which ignites the small iron wire that is suspended above the substance. The burning wire falls upon and ignites the material in the platinum crucible O. The heat from the combustion of the material raises the temperature of the water in the calorimeter cylinder. A number of readings are taken so as to secure the actual rise in temperature, caused by the combustion of the substance. Due allowances are made for the heat contributed by the combustion of the iron wire, the heat absorbed by the steel bomb

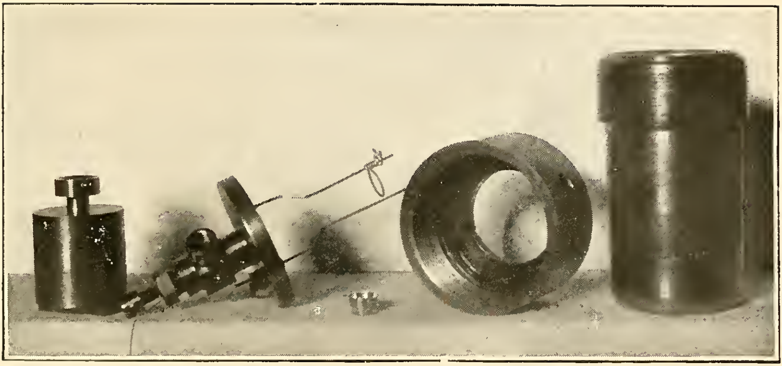

Fig. 96.—Parts of bomb calorimeter and accessories: A, pellet mold; B, cover to bomb; C, platinum dish, holding substance burned; D, collar; E, steel bomb—platinum-lined.

and for other factors that are known and under control.

The approximate amount of energy which a food will yield can be determined by the use of the following factors: Ether extract 4225, and fiber, nitrogen-free extract, and crude protein 1860. These are the numbers of calories which a pound of each of the nutrients yields.

452. Available Energy of Foods.—Since only a portion of the nutrients of foods is digestible, not all of the total caloric value is rendered available to the body. The digestion process is more complete with non-nitrogenous compounds than with the proteids. The final products of oxidation in the case of starch, sugar and digestible carbohydrates are carbon dioxid and water. These compounds undergo complete combustion. The final products of digestion of the proteids are amides, the larger portion of which is excreted as urea in the liquid waste. This compound, urea, CH_4N_2O, does not undergo complete oxidation in the body. If burned in the calorimeter, it would yield an additional amount of heat. The term available energy of a food means simply the total energy available to the body and measured in calories. The available energy is obtained by deducting from the

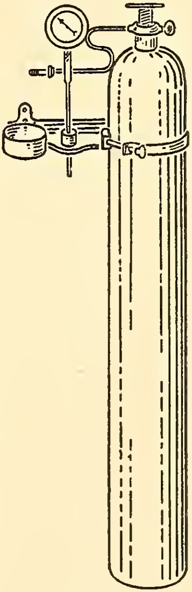

Fig. 97.

total digestible energy, the calories contained in the products, as urea, which are not completely oxidized. In the determination of the available energy of foods, the principle is the same as that explained in the section relating to the digestibility of nutrients. The total number of calories in a food is determined by the calorimeter; the number of calories in the feces is likewise determined and deducted from the total, as well as the caloric value of the liquid excrements containing urea. This gives the energy of the food available to the animal.

453. Net Energy of Foods.—In the process of digestion, particularly of coarse fodders containing much crude fiber, energy varying with the density of the tissue is required to render the food available to the body. Of the total available energy, a portion, and in some cases, a large amount is used up in rendering the food available, that is, in carrying on the process of digestion. Means have been devised whereby the approximate amount of work required on the part of the animal to render the food available can be determined. When the energy used in this way is deducted, it leaves the net energy. In the case of coarse fodders, a considerable portion of the energy is used up in the digestion of the food leaving, in some cases, only comparatively little net energy while less force is required to digest the grains, and a larger amount of energy is available to the body. The total, available, and net energy which foods produce are important factors because one of the objects of food is to supply nutrients for the production of energy.

454. Digestion of Proteids.—The insoluble proteids are acted upon by the pepsin ferment which is present in the stomach of animals. Peptones are produced by this action. Proteids which escape the action of the peptic ferment are later brought into contact with the tryptic ferment which is present in the pancreas and lower parts of the digestive tract. This ferment acts in an alkaline solution while pepsin requires a slightly acid condition. The proteids which fail to be digested by either the peptic or tryptic ferments are usually expelled as indigestible proteids. In normal digestion, the fluids of the stomach are slightly acid while those of the pancreas and intestines are alkaline. For the formation of acids and alkalies, sodium chlorid is essential. From this compound, hydrochloric acid, present in the gastric juice, is formed, also the alkaline products in the biliary and other fluids. Sodium chlorid is a normal constituent of the blood and of many of the vital fluids of the body.

After serving the various purposes in the body, as noted in Section 305, the proteids are expelled as amides in either the solid or liquid excrements, the larger portion being in the form of urea. From the time the proteids are acted upon by the soluble ferments in the digestive tract until their products are expelled from the body as amides, a large number of intermediate substances are formed. Should the proteids fail to undergo normal digestion, poisonous products called ptomaines are produced.

455. **Digestion of the Carbohydrates.**—Digestion of the carbohydrates begins with the ptyalin ferment of the saliva. Carbohydrate digestion takes place mainly

in the lower part of the digestive tract where diastase and other ferment bodies are secreted which change the insoluble carbohydrates to soluble forms. When completely digested, carbon dioxid and water are the final products. Between the soluble carbohydrates formed by the diastase and other ferments and the final products of oxidation, carbon dioxid and water, a large number of intermediate products are formed. Glycogen is one of these bodies and is a carbohydrate present in small amounts in the blood but stored up largely in the liver. The process of carbohydrate digestion is one in which the soluble ferments take an important part, changing the insoluble compounds to soluble and assimilable forms.

456. Digestion of Fats.—Bile and the intestinal fluids are the main factors which assist in the digestion of fats. After emulsion or separation into fine particles, the fats are changed to glycerin and fatty acids by the action of a ferment body. They are then absorbed and undergo slow oxidation whereby carbohydrate-like bodies are produced. These products then undergo the same general changes as the carbohydrates.

457. Oxygen Necessary for Digestion.—In order that digestion may proceed in a normal way, a liberal supply of air is necessary to oxidize the nutrients and to prevent the formation of poisonous waste products in the body. In the absence of a liberal supply of air, normal digestion fails to take place. Oxygen is equally as important as protein, fat, carbohydrates or water.

458. Factors Influencing Digestion.—There are a number of factors which influence the completeness of the process of digestion. Some of these factors are: (1) Mechanical condition of the food, (2) combination of foods, (3) amount of food consumed, (4) palatability of the food, and (5) individuality of the animal. A digestion coefficient is a variable factor capable of being influenced by these and other conditions.

459. **Mechanical Condition.**—The mechanical condition of a food, as fineness of division and density of particles, materially influences digestion. As a general rule, the finer the division the more complete is the digestion. For example, experiments with pigs have shown that wheat meal is 10 per cent. more digestible than whole wheat. Experiments with other animals, recorded in Bulletin No. 77, U. S. Department of Agriculture, Office of Experiment Stations, giving the digestibility of American feeding-stuffs, show equally large differences. The finer the division of the particles, the larger is the surface exposed to the action of the digestive fluids. The density of a material also influences its digestibility. Many foods contain a fair amount of nutrients, but their mechanical condition is such that the nutrients are not easily rendered available because of the presence of a large amount of cellulose enclosing and protecting the nutrients, and as a result, digestion and assimilation fail to take place. This is particularly true of many coarse fodders, as timothy hay and clover when allowed to become overripe and fibrous. Digestion experiments with such forage, and with that cut in early bloom, show that when cut in early bloom, it is more digestible than when over-

ripe and woody. In the case of human foods also, fineness of division of the particles favorably affects the completeness of the digestion process. Graham or coarsely granulated flour, although it contains more nutrients, is less digestible and furnishes less total available nutrients than finely granulated flour. The advisability of grinding animal foods depends entirely upon the cost of the grinding. Where it can be done on the farm at slight expense, it invariably pays to grind grains, particularly wheat, barley, millet and others which have a hard seed coat. In the feeding of coarse fodders, their mechanical condition is an important factor. When shredded corn fodder is fed, less energy is required on the part of the animal to render the nutrients available. This results in the return of a larger amount of net energy from the food.

460. Combination of Foods.—The way in which a food is combined and fed in a ration influences its digestibility. When foods are fed singly, they are not as completely digested as when fed in a well-balanced ration. For example, experiments have shown that corn alone when fed to pigs, is not as completely digested as when combined with shorts and other foods. Some foods assist in the digestion of other foods. Whenever milk is added to the ration for pigs, a larger amount of pork is secured than when the same amount of nutrients in other form is added. The milk assists in the digestion of the grains with which it is combined. Exact experiments to show the full extent to which one food influences the digestibility of another have not as yet been made. In the feeding of farm animals, however, the practical results which have been obtained show that this is an important factor.

461. Amount of Food Consumed.—In the case of human digestion experiments, results have shown that a large amount of food is not as completely digested as a smaller amount. With farm animals, the experiments have not been so decisive. In some cases, large rations have been digested as completely as smaller ones. This is undoubtedly due to individual differences of animals. Excessive amounts of foods, however, have a tendency to interfere with normal digestion and the results are not as satisfactory as when medium rations are fed.

462. Palatability.—In order to have the best results, the food should be relished by the animals. Palatability exerts a favorable influence upon digestibility and also upon the returns in animal products. Overripe and fibrous fodders are generally lacking in palatability because in the later stages of growth, there is a smaller amount of the essential oils and other products that impart palatability. The mechanical condition and the palatability of coarse fodders are closely associated, and the highest degree of digestibility of grains and fodders generally accompanies the best mechanical condition.

463. Individuality.—When a number of animals are fed the same ration, individual differences are observed. Some animals are capable of digesting all foods more completely than are others, and some are capable of digesting one food more completely than another food.

This is due to individuality in digestive power and is particularly noticeable in experiments with sheep where it has been found that all do not digest the different foods equally well. Digestion coefficients obtained in experiments with one kind of animal, as sheep, are not always applicable to other animals. Experiments with swine have shown that fiber is not as completely digested as with sheep or cows.

464. Miscellaneous Factors Influencing Digestibility.—Experiments in the cooking of foods show that cooked foods are no more completely digested by farm animals than uncooked foods. Cooking, however, is sometimes desirable in order to encourage animals to consume a larger amount of food. The wetting of food, causing fermentation, has been found to be slightly beneficial. However, if wetting is practiced, great care should be exercised to prevent excessive fermentation or the action of undesirable ferments. The drying and curing of fodders do not appear to exert any unfavorable influence upon digestibility provided leaching or excessive bleaching is avoided. Green fodders, however, appear to be slightly more digestible than cured fodders. In some cases, the laxative nature of a food prevents complete absorption of the nutrients before the material is expelled from the body.

465. Application of Digestion Coefficients.—Too close application of digestion coefficients cannot be made, but general comparisons where the experiments have been performed under similar conditions are allowable and give valuable results. The methods used for the determination of digestion coefficients have not been perfected and a number of sources of minor error are introduced in digestion experiments. In the case of the feces, the ether extract contains bile, nitrogen, cleavage products, and a number of other non-fatty compounds. Hence the figures for the digestibility of the ether extract are invariably too low. Not all of the nitrogen of the feces is in indigestible forms, hence there is a tendency for the digestibility of the crude protein to be too low, then too, it is difficult to assign an absolute nitrogen factor for the determination of the crude protein. Notwithstanding these known imperfections in determining the digestibility of the food, the general results are of great value to the farmer as they indicate ways by which the largest returns, due to the highest degree of digestibility, can be secured. Some of the digestion coefficients of the more common food materials are given in the following table which is taken from Bulletin No. 77, U. S. Department of Agriculture, Office of Experiment Stations :

DIGESTION COEFFICIENTS

	Dry matter.	Organic matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free ex't.	Ether extract.
Green Fodders.							
Timothy	63.5	65.6	32.2	48.1	55.6	65.7	53.1
Dent corn	67.8	69.8	35.6	59.7	60.2	73.7	74.1
Oats	59.5	60.9	53.4	71.8	52.8	62.6	69.2
Red clover	66.1	68.1	55.0	67.0	52.6	77.6	64.5
Silage.							
Dent corn silage	65.1	67.1	32.2	49.3	66.7	68.6	80.0
Flint " "	73.1	76.1	32.9	62.8	75.1	76.9	81.8

	Dry matter.	Organic matter.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free ex't.	Ether extract.
Dent corn silage (immature)	65.6	67.4	34.3	51.3	70.6	67.4	80.2
Cured Fodders.							
Timothy (average)	56.6	57.9	32.8	46.9	52.5	62.3	52.2
" before bloom	60.7	61.5	44.2	56.8	58.8	64.3	58.4
" past bloom	53.4	54.5	30.3	45.1	47.1	60.4	51.9
Dent corn fodder	64.3	66.1	30.7	50.4	62.2	68.0	73.6
Flint " "	68.6	71.7	42.6	60.0	74.9	70.3	71.4
Dent and flint (immature)	63.9	65.7	37.2	51.7	66.0	66.2	72.2
Dent and flint (mature)	68.2	70.7	30.6	56.7	65.8	72.2	73.9
Corn stover	57.2	59.1	32.6	35.9	64.2	57.9	70.4
Red clover	57.4	59.7	29.1	58.0	54.2	64.4	55.2
Grains and Seeds.							
Cornmeal	89.4	89.6	...	67.9	...	94.7	92.1
Gluten feed	86.3	87.3	...	85.6	78.0	89.2	84.4
" meal	89.7	90.4	...	88.2	...	89.8	94.4
Malt sprouts	67.1	67.2	...	80.2	32.9	68.1	....
Wheat bran	62.3	65.7	...	77.8	28.6	69.4	68.0
Oil-Bearing Seeds.							
Cottonseed-meal	73.7	76.1	23.7	88.4	55.5	60.6	93.3
Linseed meal (old process)	78.7	81.2	...	88.8	57.0	77.6	88.6
Roots.							
Mangels	78.5	84.8	16.4	74.7	42.8	91.3	...
Potatoes (raw)	75.7	77.0	...	44.7	...	90.4	13.0

Some of the most noticeable facts observed in the table are as follows: The highest degree of digestibility of a nutrient is usually obtained with foods which contain the largest amount of that nutrient. For example, clover hay contains more crude protein than timothy hay, and in general, the protein of clover is more completely digested than that of timothy. In the case of potatoes, there is a large amount of nitrogen-free extract compounds (starch), and in the table it will be observed that they are more completely digested than the crude protein which is present in small amounts. Whenever a food contains nutrients in small amounts they are in dilute forms, and are not as completely extracted as when present in larger amounts. The coarse fodders are not as completely digested as the grains and milled products. In the coarse fodders, the digestion coefficients range from 30 to 65, while in grains and milled products, the same nutrient ranges in digestibility from 70 to 95.

466. Digestible Nutrients of Foods.—When the total amounts of nutrients in a food are multiplied by the digestion coefficients, the available nutrients are secured. For example, clover hay contains 12 per cent. crude protein which is 60 per cent. digestible. The available or digestible crude protein of the clover hay is 7.2 ($12 \times 0.6 = 7.2$). In like manner, all of the digestible nutrients of foods are ascertained. The total amount of each nutrient is multiplied by its digestion coefficient, which gives the total available or digestible nutrients. When the average composition of American feeding stuffs and the average digestion coefficients are used, the average digestible or available nutrients are obtained. Such a table is given at the end of the chapter. In the use of this table, it should be remembered that the figures apply simply to average conditions, and are susceptible to any of the influences which affect either the composition or the digestibility of foods, and while the amounts of nutrients given are fairly constant, they nevertheless vary. It is possible by giving due care to the production of crops to secure those containing the largest amounts of nutrients, and then to feed the crops so as to secure the highest degree of digestibility, and more nutrients than are given in the tables at the close of the chapter. For example, timothy hay may contain from 5 to 9 per cent. protein. That which contains 5 per cent. is less completely digested than that containing 9 per cent. From the timothy with the highest degree of digestibility, there is about 7 per cent. of the protein digestible and available, while from that with 5 per cent. of crude protein, there is from 2.5 to 3 per cent. available. The availability of the other nutrients also is in favor of the timothy hay with the larger amount of protein. In the feeding of farm animals, particular attention should be given to the production of foods which contain the largest amounts of nutrients and to combining and using them so as to secure the highest degree of digestibility. Digestion experiments have pointed out many ways in which these objects may be accomplished, and the experiments are valuable because they indicate ways in which the largest returns can be secured from the fodders and grains raised and fed upon the farm.

Experiment 77.—Digestible nutrients of foods. Take the dimensions of one of the measures given out for the experiment and calculate its capacity in quarts, dry measure (1 quart = 67.2 cubic inches). Weigh the measure, fill it with oats and weigh again. From the tables, calculate the pounds of digestible fat, protein and carbohydrates in one quart of each of the foodstuffs. Tabulate the results as follows :

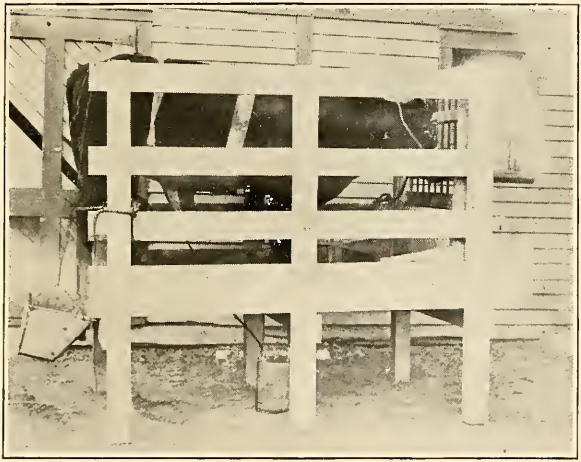

Fig. 98.—Digestion experiments.

DIGESTIBLE NUTRIENTS IN FOODS.

Name of food.	Net weight of measure.		Digestible pounds per quart.		
	Grams.	Pounds.	Fat.	Protein.	C'bhydr'ts.
Oats					
Bran					
Corn					
Oil meal					
Flour					
Shorts					

CHAPTER XXXVI

Rational Feeding of Animals

467. Balanced Rations.—A balanced ration is one which contains a sufficient amount of nutrients from a variety of foods to meet the requirements of the animal. Since the different classes of nutrients serve different purposes in the body, it is the object of rational feeding to combine foods so as to supply the nutrients in the right proportion for growth and work or production of milk, meat or wool. Rational feeding is based upon (1) the food requirements of animals, and (2) the amount of digestible nutrients in foods. The food requirements of animals are determined by experiments.

468. A Maintenance Ration is one which furnishes all of the nutrients required for maintaining the weight of the body and for performing all of its functions without allowing any nutrients for growth, work or other purposes. A maintenance ration simply sustains the animal without making allowance for growth or work. When an animal is fed a maintenance ration, it neither gains nor loses in weight; an equilibrium is established between the income and outgo of the food. The nitrogen in the proteids of the food consumed is all returned in the various waste products of the body. The element nitrogen is taken as the index for determining the maintenance requirements of animals. When the nitrogen in the waste products equals that in the food consumed, and no work has been performed, a maintenance ration has been fed. Growth, work and animal products are all produced from the excess of nutrients over those required for maintenance purposes. For example, a pig weighing 200 pounds requires about five pounds of grain per day for maintenance. If 5.5 pounds per day are fed, an increase in weight is secured only from the half pound in excess of the maintenance ration.

469. **Standard Rations.**—For feeding purposes standard rations have been proposed, giving the amounts of nutrients required by different classes of animals for different purposes. These tables have been prepared largely as the result of digestion experiments and feeding trials. The table in most common use is that prepared by Woulff and modified from time to time by various investigators. This table is given at the close of the chapter.

470. **Food Requirements of Animals.**—In the feeding of balanced rations, tables of feeding standards should be used largely as guides. It is not necessary that the rations should, in all particulars, absolutely conform to the standards given. On the other hand, it is not advisable to have the amounts of nutrients in the rations vary in any large degree from the standards. It is difficult to specify the amounts of nutrients which, under all conditions, will meet the food requirements of all classes of animals. In previous chapters, it has been shown that the composition of forage crops is subject to variation as is also their digestibility. Hence, tables giving the amounts of digestible nutrients are only approximately correct, and if assumed for all fodders and conditions, the calculated amounts of nutrients would, in some cases,

exceed and in others fall short of the standards given. On this account, it is not possible to adhere too closely to fixed rules in the rational feeding of farm animals. When foods containing the largest amounts of nutrients are produced and so fed as to secure the highest degree of digestibility, smaller amounts are required than when foods low in available nutrients are used and injudiciously fed.

471. Food Supply at Different Stages of Growth.— The amount and nature of the food consumed should vary with the period of growth. Rations for young and growing animals should contain a larger amount of protein and a smaller amount of non-nitrogenous compounds than rations for mature animals. This is because more food is required for building purposes in the early stages of growth, than in later stages when more is required for heat and energy. These facts may be observed from the table of feeding standards. For example, a calf three months old and weighing 150 pounds requires per day 0.6 pound digestible protein and 2.4 pounds digestible non-nitrogenous compounds. When the animal is a year old and weighs 500 pounds, it requires 1.3 pounds of digestible protein and 6.9 pounds of digestible non-nitrogenous compounds. The animal has increased in weight more than three times while the increased demand for digestible protein is only about twice as great, but for the non-nitrogenous compounds four and one-half times as great.

When an excessive amount of starchy and non-nitrogenous foods is fed to a young and growing animal, there is a tendency toward the production of a poor muscular and bony framework and premature fattening. To produce balanced growth in young animals, careful attention should be given to the amount and nature of the nutrients supplied in the food.

472. Food Requirements of Horses.—In feeding work horses, the object is to provide available nutrients for the production of energy because it is the energy from the food which enables the horse to do his work. Experiments have shown that for maintenance purposes, a 1000-pound horse requires about 17.5 pounds of hay per day containing a half pound of digestible protein and 7 to 7.5 pounds of digestible non-nitrogenous compounds. Such a ration does not provide any nutrients for work. In the table at the close of the chapter are given the amounts of nutrients required for average work. Any increase in work should be followed by a corresponding increase of food. Average work is best accomplished with a ration containing 22 to 24 pounds of dry matter per day of which about 1.8 pounds are digestible protein and 11 to 11.5 pounds are digestible nitrogen-free extract. It is estimated that about one-third of the energy derived from the food is utilized as useful energy in the performance of work. The best results are obtained when an even draft is made upon an animal, as experiments have shown that less energy is required for average work continuously than for severe work for a short time followed by rest.

473. Selection of Food for Horses.—For light work, 5 to 7 pounds per day of mixed grains are usually sufficient if combined with 12 to 15 pounds of coarse fodder as timothy hay. For average work, however, more food is required, and the amount of grain should be about equal in weight to the coarse fodder. For heaviest work, the grain should exceed the fodder in weight. Pure clover hay, on account of its mechanical condition, is not suitable for the feeding of horses. Timothy hay, blue grass and the different varieties of prairie hay are all suitable, if cut and cured when mediumly ripe. Early cut fodders are not as satisfactory for the feeding of horses as for the feeding of other kinds of animals. There is a tendency to confine the ration of horses too largely to one grain, oats, which usually makes an expensive ration. Experiments have shown that a larger variety of foods is desirable. Corn, barley, ground wheat, bran and other milled products are all suitable for forming part of the ration for work horses. For purposes of variety, carrots or potatoes in small amounts may be fed. Oil meal to the extent of about one-fourth pound per day is also valuable. For average work, the grinding of grains is not necessary; for hard work, coarse grinding results in a return of a larger amount of the net energy of the foods.

474. **Foods Required for Beef Production.**—According to the table of feeding standards from 25 to 30 pounds dry matter containing 2.5 to 3 pounds digestible protein, and about 15 pounds digestible carbohydrates are required for a 1000-pound animal. As pointed out by Jordan, in the "Feeding of Farm Animals," these standards are too high for economic feeding. As the result of

feeding trials, 15 pounds digestible organic matter per day for a 1000-pound animal have been found sufficient. A ration containing 15 pounds digestible dry matter, about 1.80 pounds digestible protein, 13 pounds digestible nitrogen-free extract compounds and 0.7 pound digestible ether extract was found satisfactory. When too scant an amount of protein is supplied in a ration, the meat is of poorer quality than when more is available so as to produce a normal amount of circulatory proteids in the system. In beef production, the aim should be to supply sufficient available protein for maintenance purposes, and a small amount for the other needs of the body, the fat being produced from the less expensive nutrients as carbohydrates and ether extract. When the fat is produced from an excess of protein in the food, the cost of production is unnecessarily large. The protein supply in beef production should vary with the stage of fattening. Experiments at the Pennsylvania Station show that 0.42 pound digestible protein, 6.77 pounds digestible non-nitrogenous compounds and 0.13 pound digestible ether extract are required for maintenance purposes. At different stages of growth, different amounts of food are required to produce a pound of gain. This fact is particularly noticeable in experiments at the Kansas Station from which the following data are taken :

	Grain required for 1 pound gain.
After 56 days	7.30
After 84 days	8.07
After 122 days	8.40
After 140 days	9.01
After 168 days	9.27
After 182 days	10.00

In the production of beef, palatability of the ration is an important factor ; this is best secured by combining a number of grains and coarse fodders.

475. Selection of Foods for Beef Production.—Foods which are valuable for milk production are likewise valuable for beef production ; bran, oil meal, cottonseed meal, corn, barley, shorts, middlings and screenings are among the best grain and milled products for beef production. Pasture grass, clover hay, alfalfa, corn silage, corn fodder and mixed hays are all valuable coarse fodders. Roots and tubers, to the extent of 10 to 15 pounds per day, may also be added to a beef ration. The amount of grain should range from 10 to 18 pounds per day with from 12 to 18 pounds of coarse fodder. Occasionally heavy grain feeding is resorted to in the fattening of steers. When grains and milled products are cheap, this practice is often economical as it converts a cheap grain into a more valuable marketable product. Ordinarily the cost of production is greater with a heavy grain ration than with a light or medium one, and when more than 12 pounds of grain per day is fed, the additional amount is fed at a loss. When grains and feeding-stuffs are high in price, heavy grain feeding is not economical. In the production of beef, it should be the aim to secure the larger portion of growth, as well as the larger portion of the increase during the fattening, from high-grade coarse fodders, and supplement them with medium amounts of grain and milled products. The amount of grain that can be fed economically is regulated by its cost and the market price of the beef product.

476. Food Requirements of Dairy Cows.—For the production of milk, a more liberal supply of digestible protein is required than for beef production. From 0.4 to 0.5 pound of digestible protein and from 7 to 7.5 pounds of digestible carbohydrates are required for maintenance. A ration should contain, in addition, 1.4 to 1.8 pounds digestible protein and 4 to 6 pounds digestible carbohydrates, because milk cannot be produced economically on too scant an amount of nutrients. According to the standard feeding tables, a ration for a cow giving a heavy yield of milk should contain 32 pounds dry matter, 3.3 pounds digestible protein and 13 pounds carbohydrates. For economic production of milk, this is a larger amount of protein than is necessary. Under average conditions, a ration containing about 27 pounds dry matter, 1.8 to 2 pounds digestible protein, and 11 to 13 pounds digestible carbohydrates will prove more economical than one containing larger amounts of protein. In a milk ration, proteids must be furnished for the production of the albumin and casein in the milk. In 15 pounds of milk, there is about one-half pound of proteids, as albumin and casein, and this must be supplied from the food. For the production of milk, about as much more protein is necessary to supply the energy to produce the milk as is required for maintenance and the milk proteids. In an ordinary dairy ration, about one-fourth of the proteids is recovered in the milk as casein and albumin, one-fourth is indigestible, while one-half is present in the liquid waste and represents the protein required for maintenance and the production of milk. The amount of nutrients in a dairy ration should vary with the milk yield, as given in the table of feeding standards, but it is not necessary to adhere too closely to the figures.

In the calculation of a dairy ration, it will be found that when ordinary foods are combined, the amount of ether extract or crude fat will exceed the figures given in the table. Provided the ration contains the requisite amount of digestible protein, and does not yield more than 32,000 calories, there is no objection to the crude fat amounting to 0.6 pound per day. It should not, however, in an average ration, exceed 0.75 pound.

477. Selection of Foods for Dairy Cows.—The amount of grain which a dairy cow should receive varies from 7 to 12 pounds per day. Occasionally 15 pounds can be fed economically, but, as a rule, medium grain rations of from 7 to 12 pounds produce milk and butter more economically than either light or heavy rations. As in beef-feeding, when more than 12 pounds per day of grain are fed, the additional amount is not used economically and is generally a loss. The coarse fodder in a dairy ration may vary from 18 to 50 pounds per day, according to the amount of water present in the foods. The ration should contain from 25 to 30 pounds of dry matter. When silage is fed, 20 to 40 pounds may be used because of the large amount of water present. In the feeding of roots, from 15 to 20 pounds per day will be found economical. In feeding dairy cows, it is not desirable to restrict the ration to one grain or milled product. Better results are secured from a mixture of two or three grains. No great differences have been observed in the milk-producing value of the different grains and milled products. A pound of one grain in a mixed ration will produce about as good results as a pound of another grain. For example, wheat has been found to have practically the same feeding value as corn, oats, or barley. Common farm grains will give the same yield of milk and butter-fats as bran or shorts, and, on the whole, have a tendency to produce slightly better results. Oil meal in medium amounts in a ration, produces from 20 to 25 per cent. better results than bran. Oil meal, cottonseed meal, and gluten meal all have about the same general milk-producing value.

Clover hay, corn silage, corn fodder, alfalfa and oat hay are among the most valuable coarse fodders for milk production, preference being usually given to clover hay when cut in early or full bloom. When silage is not fed, roots should always form a part of a dairy ration. Roots are valuable largely because of their palatability and the favorable influence which they exert upon digestion rather than for any large amount of nutrients.

478. Food Requirements of Swine.—The nutrients required by swine vary with the stage of growth more than in the case of other animals. In the earlier stages of growth, particular attention should be given to furnishing a liberal supply of available protein and mineral matter. A ration for a 100-pound animal should contain about 0.5 pound digestible protein and 2.5 pounds digestible carbohydrates while that for a 200-pound animal should contain about 0.6 pound digestible protein and nearly 4 pounds digestible carbohydrates. For growing pigs, a mixture of shorts and corn or shorts and barley with skim milk will be found preferable to any single grain. Skim milk should not be used in greater amounts than 3 pounds for each pound of grain. Five pounds of skim milk will produce as much gain in weight as one pound of grain. For fattening pigs the grain mixture should contain more corn than shorts. Coarse ground barley is a valuable food and produces a good quality of pork. Peas may form about one-third of the grain mixture. For fattening purposes, foods with a large amount of digestible protein are not as essential as for growing animals because the excess of protein is used for the production of fat which can be produced from less expensive nutrients as carbohydrates. The food should not be too concentrated in character. Many of the grains are so highly digestible that there is present in the digestive tract only a limited amount of insoluble matter to dilute the waste products. This is particularly true of peas and corn. Charcoal and a small amount of corn- and cob-meal are found useful to correct such deficiencies. A small amount of some forage crop as chopped, steamed or soaked clover should be at the disposal of the animal. Wheat, barley and rye, if fed, should be coarsely ground, but in the case of corn, grinding is not so essential. Bone-meal, dried blood, and meat scrap are valuable in a ration for pigs, particularly if corn is the principal grain used. Among the forage crops, rape, clover, alfalfa, sorghum and corn will be found most valuable for pork production.

479. **Food Requirements of Sheep.**—In the case of

sheep, the standard rations, as given in the tables, can be adhered to more closely than for any other class of farm animals. This is because a large number of feeding trials and experiments have been made with sheep. More nutrients are required for sheep than for beef animals, and they are capable of making equally good returns from the food consumed. Experiments by Lawes and Gilbert have shown that during the process of fattening only a slight increase in nitrogen takes place ; the gain in weight is largely an increase in fat. During the growing period, a more liberal allowance of available protein is required than for fattening. Farm foods need but little reinforcement with mill and other products for the production of mutton. Henry, in "Feeds and Feeding," states that about 500 pounds of corn and 400 pounds of clover will produce 100 pounds of gain in live weight of lambs, and he gives these figures for calculating the cost of production. The grinding of grains is not so necessary in sheep-feeding as in dairy feeding. Among the grains, corn, barley, wheat and oats have all been found valuable. Oil meal and other milled products are also suitable, provided their cost is not too high. Among the coarse fodders, clover hay, alfalfa, corn fodder and silage are particularly valuable. Roots should also form a part of the ration. Variety and palatability should be considered.

480. Calculation of Balanced Rations.—In calculating a balanced ration, the food requirements of the animal, as given in the table of feeding standards, are first noted. A reasonable variety of coarse fodders, grains and roots is selected on the basis of cost, as explained in Section

483. A trial ration is then calculated, using the approximate amounts of foods as given in the various sections relating to the food requirements of animals. The amounts of digestible nutrients in the foods selected are then calculated and the total amounts of the different nutrients determined. If these correspond with the figures given in the table, a reasonably well-balanced ration is secured. In case the nutrients are present in the right proportion but deficient in amounts, the weights of foods used are increased; if excessive, they are reduced. Should the ration be deficient in digestible protein, a small amount of some food containing a liberal supply of this nutrient may be added. Finally, when the requirement as to amounts of nutrients is satisfied, the various other factors as bulk, suitable combinations, cost, and labor involved in preparation are to be considered.

Example.—Calculate a ration for a dairy cow. The standard ration calls for 1.8 to 2 pounds digestible protein and from 10 to 12.5 pounds digestible carbohydrates. It is necessary to combine the coarse fodders and grains so as to secure approximately these amounts of nutrients. A trial ration is calculated, composed of 10 pounds each of clover-hay and corn fodder, 20 pounds of mangels, 5 of bran and 3 of oats. The digestible nutrients in these materials, as given at the close of the chapter, are as follows :

DIGESTIBLE NUTRIENTS.

	Protein.	Fat.	Carbohydrates, etc.
Wheat bran	12.9	3.4	40.1
Mangel beets	1.1	0.1	5.4
Clover hay	6.8	1.7	35.8
Corn fodder	2.5	1.2	34.8
Oats	9.2	4.2	47.3

These figures are on the basis of 100 pounds. The amounts of nutrients in one pound are found by moving the decimal point two places to the left. Multiplying the pounds of food by the per cent. of digestible nutrients, the pounds of digestible nutrients will be found to be as follows:

POUNDS OF DIGESTIBLE NUTRIENTS.

Pounds.	Protein.	Fat.	Carbohydrates, etc.
10 Clover hay	0.68	0.17	3.58
10 Corn fodder	0.25	0.12	3.48
20 Mangel-wurzels	0.22	0.02	1.08
5 Bran	0.64	0.16	2.00
3 Oats	0.28	0.13	1.42
	2.07	0.60	11.56

Compared with the standard ration, it will be observed that the amounts of nutrients are approximately as given in the table, suggesting that as far as total nutrients are concerned, the ration is a reasonable one. The coarse fodder, grain, and roots are about in the proportions given in Section 477. As to the effects of the various foods, the bran, mangels, and clover hay might possibly prove somewhat laxative in character, and while the ration supplies all of the requisites, as dry matter and amount of nutrients, it would be necessary to note the effect upon the animal, before concluding that it was satisfactory in all respects.

481. Nutritive Ratio.—The nutritive ratio is the ratio which exists between the digestible protein and the digestible non-nitrogenous compounds. A nutritive ratio of 1 to 6.7 means that for every 1 pound of crude protein there are 6.7 pounds of digestible non-nitrogenous compounds. A wide nutritive ratio means a large amount of non-nitrogenous to nitrogenous compounds, while a narrow nutritive ratio means a small amount of non-nitrogenous to nitrogenous compounds.

To calculate the nutritive ratio, first determine the pounds of digestible protein in the food used, then the pounds of digestible carbohydrates, etc. Multiply the pounds of digestible ether extract by 2.2 because the fat produces 2.2 times as much heat, consequently is considered 2.2 times more concentrated than the nitrogen-free extract compounds. Add the digestible fiber, nitrogen-free extract and corrected ether extract and divide the sum by the digestible protein; the result is the nutritive ratio. The nutritive ratio of the ration given is 6.57 $(0.6 \times 2.2 = 1.32)$ $(1.32 + 11.56 = 12.88)$ $(12.88 \div 2.07 = 6.02)$.

482. Caloric Value of Rations.—The caloric value of a ration is determined by multiplying the pounds of digestible ether extract by the factor 4225 and adding this to the number secured by multiplying the sum of the digestible protein and carbohydrates by 1860. As used in the calculation of rations, the carbohydrates include the nitrogen-free extract compounds and the digestible fiber. The term carbohydrates is used in the broad rather than the restricted sense.

Problem 1.—Calculate a ration for a 1200-pound horse at light work. Use any foods desired.

Problem 2.—Calculate a ration for a 1200-pound horse at heavy farm labor.

Problem 3.—Calculate a ration for a pig weighing 100 pounds.

Problem 4.—Calculate a ration for a pig weighing 250 pounds.

Problem 5.—Calculate a ration for a dairy cow giving a full flow of milk.

Problem 6.—Calculate a dairy ration for average milk yield.

Problem 7.—Calculate a ration for a sheep weighing 100 pounds.

Problem 8.—Calculate a ration for a growing steer weighing 500 pounds.

Problem 9.—Calculate a ration for a 1200-pound steer, fattening period.

483. Comparative Cost and Value of Grains.—The market value of grains frequently differs from their actual food value. That is, a given sum of money if invested in one food article will often procure a larger amount of digestible protein and other nutrients than if invested in other foods. To illustrate: If corn is 50 cents and oats 30 cents per bushel, $1.00 will purchase either 112 pounds of corn or 107 pounds of oats. Which is the cheaper and more valuable for feeding purposes? The digestible nutrients in 100 pounds of corn and oats are as follows:

	Digestive nutrients.		Pounds per hundred.
	Protein.	Fat.	Carbohydrates, etc.
Corn	7.9	4.3	66.7
Oats	9.2	4.2	47.3

The amounts of digestible nutrients in 112 pounds of corn and 107 pounds of oats obtained by multiplying by the per cent. of digestible nutrients are:

	Pounds.	Protein.	Fat.	Carbohydrates.	Calories.
Corn	112	8.85	4.82	74.7	175,684
Oats	107	9.84	4.50	50.6	131,407

There is a difference of about 1 pound of digestible protein in favor of the oats and 24 pounds of digestible carbohydrates in favor of the corn; the dollar's worth of corn would also contain about 44,000 more calories. At the prices given, corn rather than oats would more economically form the larger portion of a grain ration for work-horses, beef and dairy animals, and swine and sheep. For growing animals, however, a large amount of corn is not desirable.

In deciding the comparative value of foods on the basis of their nutrient content, preference should usually be given to the protein, but when the difference in digestible protein is small, the preference should be given to the food containing the largest amount of available carbohydrates and number of calories. Comparisons between foods which are too unlike in character of nutrients cannot safely be made. It is not possible to assign an absolute value to any food upon the basis of any one or all of its digestible nutrients, because the comparative value of the different nutrients has not, as yet, been definitely ascertained. In the selection of foods, it will frequently be found that a given sum of money can best be invested in the purchase of two foods, one nitrogenous and the other non-nitrogenous, rather than in the purchase of one. The results of actual feeding standards should also be considered before definitely selecting foods. When both the available nutrients and the results of feeding experiments are considered, an accurate idea of the comparative cost and value of grains and milled products can be formed.

Problem.—Complete the following table and calculate the available nutrients and calories that can be procured for $1 when the various foods are at different prices. In making the calculations, use the prices of your local or home market. Select three of the cheapest and three of the most expensive foods from the list.

	Price per bushel or ton.	Pounds for $1.00.	Nutrients procurable for $1.00. Pounds digestible nutrients.			
			Protein.	Carbohydrates.	Ether extract.	Calories.
Corn						
Oats						
Barley						
Wheat						
" bran						
" shorts						
Oil meal						
Linseed meal						
Cottonseed meal						
Gluten meal						

484. Sanitary Conditions.—Satisfactory results in the feeding of animals can be secured only under the best sanitary conditions. When animals are kept in crowded quarters, deprived of pure air and sunlight, they fail to make the best use of the food consumed. Carbon dioxid thrown off from the lungs and ammonia produced from decaying manure form ammonium carbonate, a volatile and irritating compound. Sunlight is an important factor for promoting animal growth. Experiments with growing calves have shown that under the same conditions of feed and management, animals reared with an abundance of sunlight make better gains in weight, and are more vigorous than those confined in dark quarters. The best results are obtained in the feeding of animals when their surroundings are most sanitary. A large amount of available energy is often lost in warming up cold, wet bedding. Pure water, pure air, sunlight, clean quarters and dry bedding are as necessary to animals as is a well-balanced ration.

TABLE OF FEEDING STANDARDS.

			Per 1000 lbs. live weight, daily. Digestible organic substances.				
Kind of animal.		Dry substance. lbs.	Protein. lbs.	Carbohydrates. lbs.	Fat. lbs.	Total. lbs.	Nutritive ratio 1:
Fattening bovines		30	2.5	15.	0.5	18.	6.5
Milk cows:							
Daily milk yield, 11 lbs		25	1.6	10.	0.3	11.9	6.7
Daily milk yield, $16\frac{1}{2}$ lbs		27	2.	11.	0.4	13.4	6.
Daily milk yield, 22 lbs		29	2.5	13.	0.5	16.	5.7
Daily milk yield, $27\frac{1}{2}$ ibs		32	3.3	13.	0.8	17.1	4.5
Sheep		22	1.3	11.	0.3	13.5	..
Fattening sheep, first period		30	3.	15.	0.5	18.5	5.4
Horses:							
Light work		20	1.5	9.5	0.4	11.4	7.
Moderate work		24	2.	11.	0.6	13.6	6.2
Severe work		26	2.5	13.3	0.8	16.6	6.
Fattening swine:							
First period		36	4.5	25.	0.7	30.2	5.9
Second period		32	4.	24.	0.5	28.5	6.3
Third period		25	2.7	18.	0.4	21.1	7.
Growing cattle (dairy breeds).							
Age in months.	Live weight per head, lbs.						
2– 3	150	23	4.	13.	2.	21.	4.5
3– 6	300	24	3.	12.8	1.	16.8	5.1
6–12	500	27	2.	12.5	0.5	15.	6.8
12–18	700	26	1.8	12.5	0.4	14.7	7.5
18–24	900	26	1.5	12.	0.3	13.8	8.5

			Per 1000 lbs. live weight, daily. Digestible organic substances.				
Kind of animal. Age in months.	Live weight per head, lbs.	Dry substance. lbs.	Protein. lbs.	Carbohydrates. lbs.	Fat. lbs.	Total. lbs.	Nutritive ratio 1:
Beef breeds:							
2– 3	...	23	4.2	13.	..	19.2	4.2
3– 6	...	24	3.5	12.8	..	17.8	4.7
6–12	...	25	2.5	13.2	..	16.4	6.
12–18	...	24	2.	12.5	..	15.	6.8
18–24	...	24	1.8	12.	..	14.2	7.2
Sheep:							
4– 6	65	26	4.4	15.5	0.9	20.8	4.
8–11	100	24	3.0	14.3	0.5	17.8	5.2
Swine:							
2– 3	45	44	7.6	28.0	1.0	35.7	4.0
3– 5	110	35	5.0	23.1	0.8	28.9	5.0
5– 6	150	33	4.3	22.3	0.6	27.2	5.5

DIGESTIBLE NUTRIENTS IN FODDERS.

		Digestible nutrients in 100 lbs.		
Name of feed.	Dry matter in 100 lbs.	Protein.	Carbohydrates.	Ether extract.
Corn (all analyses)	89.1	7.9	66.7	4.3
Dent corn	89.4	7.8	66.7	4.3
Flint corn	88.7	8.0	66.2	4.3
Sweet corn	91.2	8.8	63.7	7.0
Corn cob	89.3	0.4	52.5	0.3
Corn and cob meal	84.9	4.4	60.0	2.9
Corn bran	90.9	7.4	59.8	4.6
Gluten meal	91.8	25.8	43.3	11.0
Germ meal	89.6	9.0	61.2	6.2
Hominy chops	88.9	7.5	55.2	6.8
Wheat	89.5	10.2	69.2	1.7
Wheat bran	88.1	12.2	39.2	2.7
Wheat bran (spring wheat)	88.5	12.9	40.1	3.4
Wheat bran (winter wheat)	87.7	12.3	37.1	2.6

Name of feed.	Dry matter in 100 lbs.	Digestible nutrients in 100 lbs.		
		Protein.	Carbohydrates.	Ether extract.
Wheat shorts	88.2	12.2	50.0	3.8
Wheat middlings	87.9	12.8	53.0	3.4
Wheat screenings	88.4	9.8	51.0	2.2
Rye	88.4	9.9	67.6	1.1
Rye bran	88.4	11.5	50.3	2.0
Rye shorts	90.7	11.9	45.1	1.6
Barley	89.1	8.7	65.6	1.6
Malt sprouts	89.8	18.6	37.1	1.7
Brewers' grains (wet)	24.3	3.9	9.3	1.4
Brewers' grains (dried)	91.8	15.7	36.3	5.1
Oats	89.0	9.2	47.3	4.2
Oat feed or shorts	92.3	12.5	46.9	2.8
Oat hulls	90.6	1.3	40.1	0.6
Buckwheat	87.4	7.7	49.2	1.8
Buckwheat bran	89.5	7.4	30.4	1.9
Flax seed	90.8	20.6	17.1	29.0
Linseed meal (old process)	90.8	29.3	32.7	7.0
Linseed meal (new process)	89.9	28.2	40.1	2.8
Cottonseed meal	91.8	37.2	16.9	12.2
Coarse Fodders.				
Fodder corn (green)	20.7	1.0	11.6	0.4
Fodder corn (field-cured)	57.8	2.5	34.6	1.2
Corn stover (field-cured)	59.5	1.7	32.4	0.7
Fresh Grass.				
Pasture grasses (mixed)	20.0	2.5	10.2	0.5
Kentucky blue grass	34.9	3.0	19.8	0.8
Timothy, different stages	38.4	1.2	19.1	0.6
Oat fodder	37.8	2.6	18.9	1.0
Peas and oats	16.0	1.8	7.1	0.2
Hay.				
Timothy	86.8	2.8	43.4	1.4
Redtop	91.1	4.8	46.9	1.0
Kentucky blue grass	78.8	4.8	37.3	2.0

Name of feed.	Dry matter in 100 lbs.	Digestible nutrients in 100 lbs.		
		Protein.	Carbohydrates.	Ether extract.
Hay (continued).				
Hungarian grass	92.3	4.5	51.7	1.3
Mixed grasses	87.1	5.9	40.9	1.2
Rowen (mixed)	83.4	7.9	40.1	1.5
Oat hay	91.1	4.3	46.4	1.5
Straw.				
Wheat	90.4	0.4	36.3	0.4
Oat	90.8	1.2	38.6	0.8
Fresh Legumes.				
Red clover, diff. stages	29.2	2.9	14.8	0.7
Alsike, bloom	25.2	2.7	13.1	0.6
Crimson clover	19.1	2.4	13.9	0.5
Legume, Hay and Straw.				
Red clover, medium	84.7	6.8	35.8	1.7
Red clover, mammoth	78.8	5.7	32.0	1.9
Alsike clover	90.3	8.4	42.5	1.5
Alfalfa	91.6	11.0	39.6	1.2
Cow pea	89.3	16.8	38.6	1.1
Silage.				
Corn	20.9	0.9	11.3	0.7
Roots and Tubers.				
Potato	21.1	0.9	16.3	0.1
Sugar-beet	13.5	1.1	10.2	0.1
Mangel beet	9.1	1.1	5.4	0.1
Rutabaga	11.4	1.0	8.1	0.2
Carrot	11.4	0.8	7.8	0.2
Miscellaneous.				
Pumpkin (field)	9.1	1.0	5.8	0.3
Beet-pulp	10.2	0.6	7.3	..
Cow's milk	12.8	3.6	4.9	3.7
Skim milk (gravity)	9.6	3.1	4.7	0.8
Skim milk (centrifugal)	9.4	2.9	5.2	0.3
Buttermilk	9.9	3.9	4.0	1.1
Whey	6.6	0.8	4.7	0.3

CHAPTER XXXVII

Composition of Animal Bodies

485. **Water and Dry Matter.**—About half of the live weight of an animal is water. In fat animals, the proportion of water is less than in lean animals. The same general classes of organic compounds present in plants, as non-nitrogenous and nitrogenous, are also present in animal bodies ; the animal forms, however, are usually somewhat more complex than the plant forms. Animal bodies are characterized by containing a high per cent. of fat and proteid materials and a low per cent. of non-nitrogenous compounds other than fat.

486. **Mineral Matter.**—The ash elements in the animal body are the same as those found in plants, and are nearly all furnished from vegetable sources. The body of an animal, live weight basis, contains from 2 to 4 per cent. of mineral matter, from a half to three-fourths of which is present in the bones, while the remainder is present both in solution in the various fluids, as the blood, chyle, etc., and deposited and combined with the solid and fleshy tissues of the body. Silicon in animal bodies is found mainly in the hair, wool and feathers. Sodium and chlorin, while unnecessary to plants, are absolutely necessary to animals. A thousand parts of blood yield about 4 parts of mineral matter, of which 1.2 are sodium chlorid. In the blood, salt is necessary as a solvent for the proteids.

The per cent. of ash in the carcasses of different animals varies, being greatest in the half-fat steer or ox, and least in the fat pig. In the process of fattening, the percentage amount of ash is decreased.

As in the case of the plant, the mineral matter of the animal body must be secured and assimilated in the early stages of growth. Young pigs, or other young animals, fed exclusively on a food which like corn is poor in digestible mineral matter, have bones which are weak and do not furnish a framework strong enough for the perfect development of the body in its last stages of growth. The same elements which are essential for plant growth are also essential for animal growth.

487. **Fat.**—The per cent. of fat in the carcass of animals ranges from 14 to 45 per cent. of the live weight. The carcasses of fattened steers of good quality consist of about one-third fat; in moderately fat sheep there is somewhat more, while the largest amount is present in the body of the very fat pig, with the very fat sheep as a close competitor. "It is thus seen that animal food of reputed high quality as sold by the butcher, and to which such a highly nitrogenous character is usually attributed, will consist of fat to the extent of one-third to one-half of its total weight." (Lawes & Gilbert.)

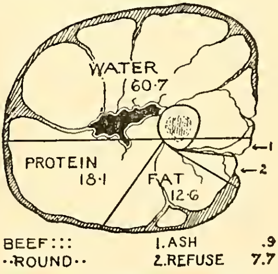

Fig. 99.—Composition of meat.

488. **Nitrogenous Matter** is present to the extent of 10 to 18 per cent. in the live animal, being least in the very

fat pig and most in the half-fat ox. The offal parts, as the head, feet, tail, hair, wool, and horns, are quite rich in nitrogen but not so rich as the flesh. Beef-yielding animals, on the whole, contain rather more nitrogenous compounds than sheep, which in turn contain more than pigs. A large amount of the nitrogenous compounds of sheep and lambs is present in the wool (50 to 55 per cent). About 75 per cent. of the carcass of the sheep is consumed as food; thus it will be seen that much less than half of the total nitrogen is really made use of as human food. Of the fattened pig, about three-fourths of the nitrogenous compounds are in the edible carcass. From 6 to 7 parts are in the bone, and about one-quarter is in the offal. About 8 per cent. of the nitrogenous compounds of the offal and a little over three-fourths of the total nitrogenous compounds of the pig are consumed as food. About two-thirds of the entire nitrogen of the calf and steer are in the butcher's carcass, and about 12 per cent. is in the bones. From 5 to 7 per cent. of the nitrogen of the offal parts and about 60 per cent. of the total nitrogen of the steer are utilized as human food.

In the table of relative composition of animal bodies, it will be noted that the mineral matter increases and decreases with the nitrogenous matter. In the carcasses of all animals, it will be observed that the amount of fat always exceeds the amount of nitrogenous matter, except in the case of the lean calf. In the bodies of animals in good condition, there is usually twice as much fat as dry protein. The following table is from the extensive work of Lawes and Gilbert.

PROXIMATE COMPOSITION OF ANIMALS.

	Per cent. in carcass.					In live weight of animal.				
	Ash.	Nitrogenous.	Fat.	Dry matter.	Water.	Ash.	Nitrogenous.	Fat.	Water.	Dry matter.
Fat calf	4.48	16.6	16.6	33.7	62.3	3.80	15.2	14.8	63.0	33.8
Half-fat ox	5.56	17.8	22.6	46.0	54.0	4.66	16.6	19.1	51.5	40.3
Fat ox	4.56	15.0	34.8	54.4	45.6	3.92	14.5	30.1	45.5	48.5
Fat lamb	3.63	10.9	36.9	51.4	48.6	2.94	12.3	28.5	47.8	43.7
Store sheep	4.36	14.5	23.8	42.7	57.3	3.16	14.8	18.7	57.3	36.7
Half-fat, old sheep	4.13	14.9	31.3	50.3	49.7	3.17	14.0	23.5	50.2	40.7
Fat sheep	3.45	11.5	45.4	60.3	39.7	2.81	12.2	35.6	43.4	50.6
Extra fat sheep	2.77	9.1	55.1	67.0	33.0	2.90	10.9	45.8	35.2	59.6
Store pig	2.57	14.0	28.1	44.7	55.3	2.67	13.7	23.3	55.1	39.7
Fat pig	1.40	10.5	49.5	61.4	38.6	1.65	10.9	42.2	41.3	54.7

489. Proteids of Meat.—Lean meat, fat-free, is a concentrated nitrogenous material composed mainly of proteids but containing also small amounts of amides, albuminoids and in some cases, alkaloidal bodies. The proteids are present mainly in insoluble forms; a small amount, however, is soluble. The principal soluble meat proteids are albumin and syntonin.

490. Albumin.—The formula $C_{72}H_{112}N_{18}SO_{22}$ has been tentatively assigned to albumin. The amount of albumin in meats ranges from 0.6 to 5 per cent. Liebig gives as a mean 2.96 per cent. The lean meat of the pig as well as that of poultry contains a relatively large amount. Albumin is soluble in cold water, and is coagulated at a temperature of 157° to 163° F. and of 69° to 75° C. Dilute acids convert albumins into acid albuminates while alkalies produce alkali albuminates. The albuminates are proteids derived from albumins and other proteids by the action of acids or alkalies.

491. Myosin.—Myosin is obtained from meat by extraction with a weak solution of common salt. The myosin dissolves in the salt solution and is precipitated by heat and chemicals (see Experiments 60 and 61). Myosin is a globulin and in the living animal is present largely in soluble forms.

492. Syntonin has the same general relationship to myosin as dextrin has to starch. Dextrin is derived from starch and syntonin is derived from myosin. Syntonin is an acid albuminate formed by the action of dilute acids. The amount of syntonin and myosin in meats is small, never exceeding, according to Hoffman, 2 or 3 per cent.

493. **Hemoglobin.**—When fresh meat is soaked in cold water, the solution becomes red in color on account of the hemoglobin which is extracted. Hemoglobin is a proteid which imparts the red color to the blood and is coagulated by heat at a temperature of 128° to 132° F. There is a sufficient amount of various salts in the blood to dissolve some of the fibrin proteids which are precipitated at a temperature of about 140° F. or 60° C.

494. **Insoluble Proteids.**—The larger portion of the nitrogenous material of the muscles is in the form of insoluble muscular fiber. From 90 to 95 per cent. of the total nitrogenous matter of fat-free lean meat is present in soluble forms. In the grains, various insoluble proteids are found and in the different meats different kinds of insoluble proteids are present. Meats differ both as to the kinds and proportional amounts of the several proteids which they contain.

495. **Peptones.**—When muscular fiber is acted upon by some ferments, peptones are produced. Only a small amount of peptones is present in meat. When meat is in cold storage to undergo the curing process before it is placed upon the market, the peptonizing process takes place to a slight extent. If the process is too long continued, ptomains, which are poisonous compounds, may develop. When meat of the best quality is produced, long curing is unnecessary.

496. **Keratin** is an amide compound present in meat

juices in small amounts; 100 pounds of meat contain from 0.07 to 0.32 of a pound. Like other amides, it possesses less food value than protein. Keratin, sarkin and allied bodies are not coagulated by heat, but are gradually decomposed and give off characteristic odors when meat is being cooked. Keratin and sarkin are present in large amounts in beef extracts and although they possess no direct food value, they impart palatability and are mainly valuable on this account.

497. Albuminoids, Gelatin.—When bone or muscular tissue is subjected to the action of boiling water, gelatin separates upon cooling and standing. Gelatin is quite different in chemical composition from albumin, muscular fiber and other proteids. Hoffmeister gives the formula as $C_{102}H_{151}O_{39}$. It contains no sulfur, while proteids contain from 1 to 2 per cent. Gelatin may prevent the rapid depletion of the protein of the body but cannot take its place as a nutrient. The approximate amounts of the nitrogenous compounds in lean meat are given in the following table from which it will be observed that only a small part is present in the meat juices.

THE NITROGENOUS COMPOUNDS OF MEAT.

		Per cent.
1. Proteids	Muscular fiber	12 to 18
	Albumin	0.5 to 2.0
	Myosin	0.4 to 0.6
	Syntonin	.. ..
2. Albuminoids	Gelatin, etc	2.0 to 5.0
3. Amides	Keratin	0.07 to 0.34
	Sarkin	0.01 to 0.03
	Urea	....
4. Alkaloids (ptomaines)		Occasionally traces.

498. Influence of Food upon the Composition of Animal Bodies.—The nature of the food consumed has a noticeable effect upon the composition of the animal body. The food affects both the amount of meat produced and its composition. As a general rule, an unbalanced ration, particularly one with a large amount of non-nitrogenous compounds, produces flesh that is poor in circulatory proteids. But few systematic experiments have been made to study the influence of food upon the composition of animal bodies.

499. Composition of the Human Body.—Halliburton states that the human body contains 58.5 per cent. water. The amount at different stages of life varies; in later life, the body contains less than during youth. Water is present in all parts of the body; enamel contains 2 per cent., the gray matter of the brain 85 to 86 per cent., bone about 50 per cent., and muscle 75 per cent. The amount of fat varies between quite wide limits; normally, Moleschott states that it makes up from 4 to 5 per cent. of the weight of the body. Adipose tissue contains about 85, marrow 96, and nerves 22 per cent. fat. Twenty-five per cent. of the muscle is solid matter, of which 21 per cent. is proteid and albuminoid material, and 4 per cent. is fat and nitrogenous extractive bodies. Mineral matter is present in small amounts combined with the muscular and other tissues and in solution in the various fluids and secretions.

CHAPTER XXXVIII

Rational Feeding of Men

500. Similarity in the Principles of Human and Animal Feeding.—The rational feeding of men is founded upon the same principles as the rational feeding of animals. It is the object in each case to supply the body with the right kinds and amounts of nutrients to meet all of its demands. It is not possible in either human or animal feeding to establish inflexible standards.

501. Dietary Standards.—The standard rations which have been proposed by Atwater, Voit and others call for about one-fourth of a pound each of fat and protein and a pound of carbohydrates in the ration of a man at average muscular labor. Such a ration should yield about 3,200 calories. The actual amount of nutrients consumed by laborers does not always conform to this standard. For example, studies have shown that the negro laborer in the South often, by choice, consumes less than 0.1 pound per day of protein, while a well-fed mechanic frequently consumes over 0.5 pound per day. While only tentative standards are proposed, experiments and dietary studies have shown that the best results are obtained in the feeding of men, as in the feeding of animals, when the ration conforms within reasonable limits to the standard. By a dietary standard is meant the approximate amount of nutrients which the daily ration should contain. Such a standard as proposed by Atwater is as follows:

	Protein. lb.	Fat. lb.	Carbohydrates. lbs.	Fuel value. calories.	Nutritive ratio.
Man with little physical exercise	0.20	0.20	0.66	2450	5.5
Man with light muscular work	0.22	0.22	0.77	2800	5.7
Man with moderate muscular work	0.28	0.28	0.99	3520	5.8
Man with active muscular work	0.33	0.33	1.10	4060	5.6
Man with hard muscular work	0.39	0.55	1.43	5700	6.9

502. Amount of Foods Consumed per Day.—In combining foods to form human rations, there should be, as in animal rations, a variety of foods and no food article should be used in excessive amounts. The approximate amounts of food consumed per day by a man at average labor, are as follows:

	Range. Ounces.	Average. Pound.
Bread	6 to 14	0.50
Butter	2 to 5	0.12
Potatoes	8 to 16	0.75
Cheese	1 to 4	0.12
Beans	1 to 4	0.12
Milk	8 to 32	....
Sugar	2 to 5	0.20
Meat	4 to 12	0.25
Oatmeal	1 to 4	0.12

In a balanced ration, it is the aim to obtain from all of the foods approximately 0.25 pound each of fat and protein and a pound of carbohydrates. In case of severe work, larger amounts of nutrients, as indicated in the table, are necessary. The composition of human foods is given in the tables at the close of the chapter.

In calculating the amounts of nutrients in fractions of a pound, the percentage composition of the food is multiplied by the weight used, as in calculating animal rations (see Section 480).

503. Calculating a Balanced Ration.—The various articles of food should be selected according to cost, nutritive value, purposes for which they are desired, amount and kind of work to be performed, and individual preferences. When bread, butter, milk, potatoes, sugar, oatmeal, cornmeal, beef, ham and eggs, are to be combined to form a ration, such amounts are taken as will yield approximately 0.25 pound each of protein and fat, and a pound of carbohydrates. Such a combination would be as follows:

		Nutrients.			
Foods.	Amount per day. Ounces.	Protein. Pound.	Fat. Pound.	Carbohydrates. Pound.	Calories.
Ham	4	0.04	0.09	....	480
Eggs (2)	..	0.03	0.02	....	136
Bread	8	0.05	0.01	0.28	650
Butter	2	....	0.11	....	450
Potatoes	12	0.02	....	0.14	285
Milk	16	0.04	0.04	0.05	325
Sugar	2	....	....	0.12	200
Oatmeal	2	0.02	0.01	0.09	230
Beef (stew)	4	0.04	0.05	....	250
Cornmeal	4	0.02	0.01	0.18	420
		0.26	0.34	0.86	3426

This ration contains 0.26 pound protein, 0.34 pound fat, 0.86 pound carbohydrates and yields 3,426 calories. While it contains somewhat more fat and slightly less carbohydrates than the standard, it is sufficiently near the standard for all practical purposes. Some vegetables and fruits should be added to the ration not so much with the object of increasing the nutrients as for the purpose of greater variety and palatability. In this ration, the nutrients are secured from a variety of sources, the largest amount of protein coming from the bread. About one-third of the protein is supplied in the form of meat, one-fourth by the eggs and milk, while the balance is secured from the vegetable foods. Bread, potatoes, cornmeal and sugar supply most of the carbohydrates, the two ounces of sugar supplying nearly 14 per cent.

In combining foods to form balanced rations, meats, beans, cheese, milk, bread and oatmeal supply protein, while pork, ham, bacon and other fat meats, butter, cheese and milk supply the fats. Carbohydrates are supplied more liberally from bread, rice, cornmeal, cereals, potatoes, sugar and vegetables.

504. Comparative Cost and Value of Foods.—With human as with animal foods, the market price does not, as a rule, correspond with their nutritive value. When foods differ widely in cost, their relative values can be approximately determined by comparing the amounts of

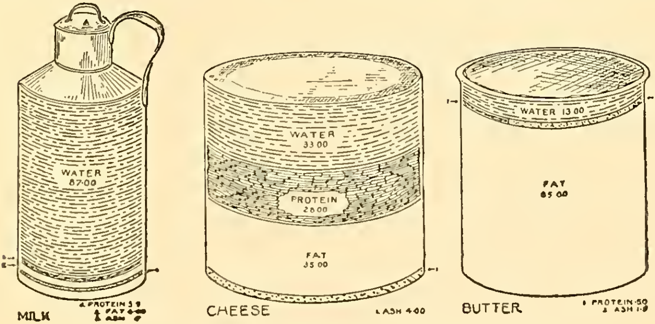
WATER 87.00
MILK
PROTEIN 3.9
FAT 4.00
ASH
WATER 33.00
PROTEIN 28.00
FAT 35.00
CHEESE
ASH 4.00
WATER 13.00
FAT 85.00
BUTTER
PROTEIN .50
ASH 1.5

Fig. 100.—Comparative composition of milk, cheese, and butter.

nutrients which a given sum of money will procure in each case. The principle is the same as in the comparison of cost and value of animal foods, Section 483.

In making comparisons, preference cannot be given to any single nutrient. In general, however, foods which supply the largest amount of protein for a given sum of money are cheapest and most economical provided there is no great difference in the amounts of fat and carbohydrates. When there is but little difference in protein content, preference should be given to foods yielding the largest number of calories.

In order to calculate the nutrients which can be procured for a given sum of money, first determine the pounds of food, then multiply the weight by the percentage composition, using the figures in the tables.

When round steak is 15 cents per pound and milk 5 cents per quart, the amounts of nutrients which can be purchased for 15 cents are as follows:

		15 cents will buy			
	lbs.	Protein. lb.	Fat. lb.	Carbohydrates. lb.	Calories.
Round steak	1	0.18	0.12	....	870
Milk	6	0.21	0.24	0.30	1950

Three quarts of milk or six pounds contain 0.03 pound more protein and 0.12 pound more fat and yield over 1,000 calories more than a pound of round steak costing the same. Milk at 5 cents per quart should be used liberally in the ration when steak is 15 cents or more per pound. It does not follow that meat should be entirely excluded from the ration in favor of milk but the nutrients indicate that milk should be used in liberal amounts.

Problem 1.—Calculate a balanced ration for a man at hard muscular labor and give the cost of the food articles required.

Problem 2.—Calculate a ration for a man with little physical exercise, giving cost of ration.

Problem 3.—Calculate the amounts of food and the nutrients required for a family of seven for ten days, three of the family to be considered as consuming each 0.8 as much as an adult. Calculate the cost of the food. Then calculate, on the same basis, the probable amounts of food for one year with cost, adding 20 per cent. additional for fluctuations in market prices and foods not included in the ten-day list.

Problem 4.—How do beef and mutton compare as to nutrients when they are the same price per pound?

Problem 5.—Calculate the comparative amounts of nutrients that can be procured when cheese is 16 cents and loin steak 20 cents per pound, and also when cheese is 20 cents and loin steak is 16 cents.

Problem 6.—How do the nutrients in chicken at 12 cents per pound compare with those in round steak at 14 cents per pound?

Problem 7.—How does flour at 2 cents per pound compare in nutritive value with a cereal breakfast food at 10 cents per pound, and having the same composition as whole wheat?

505. Factors Influencing Digestibility.—The factors, discussed in Chapter XXXV, which influence the digestibility of animal foods also influence the digestibility of human foods. The mechanical condition of the food and the method of preparation have a more pronounced effect in a human than in an animal ration. The term digestibility has, by some physiologists, been used to designate ease of digestion rather than completeness of the process, foods which are easily digested and require but little work of the digestive tract being termed digestible, while those which require a larger amount of work are said to be indigestible. Some confusion has arisen from this use of the term digestible. For example, rice is frequently called a digestible food and cheese an indigestible food. Digestion experiments have shown that cheese is more completely digested than rice. A food which is easily digested is not necessarily completely digested.

Individuality influences the digestibility of foods to a marked extent. For example, digestion experiments have shown a difference of over 14 per cent. in digestibility of the protein in a mixed ration composed of bread, milk and beans. There is a greater difference between individuals as to the ease of digestion than as to the completeness. Since digestion is largely a biochemical process, its completeness is necessarily influenced by the activity of the cells in the digestive tract. The combining of foods influences digestibility. For example, milk in a ration exerts a favorable influence upon the digestibility of the other foods with which it is combined. This is because of the presence in milk of enzymes or soluble ferments. Experiments have shown that 12.5 per cent. of the protein in a sterile food, as toast, is capable of being digested by the soluble ferments of milk.

The method of cooking and preparing foods also exerts an influence upon their digestibility. Cooking changes both the physical and chemical composition of foods. The cell walls of vegetables and cereals are broken and the starch granules ruptured, thus exposing them to more thorough action of the digestive fluids. Cooking influences the ease or rapidity of digestion to a greater extent than it does the completeness of the process. The carbohydrates are favorably influenced by the action of heat while, in some cases, prolonged heat may make the proteids less digestible. In pasteurized milk, for example, the proteids are slightly less digestible than in pure fresh milk, while in sterilized milk, the digestibility is noticeably lessened. As in the case of animals, the mechanical condition of a food influences both the ease and the completeness of the process. With persons of sedentary habits, the best results are secured when a small amount of some coarsely granulated food is present. A large amount of such foods, however, is not suitable in the ration of a hard working man because of lack of availability of the nutrients.

506. Requisites of a Ration.—Reasonable combinations should be made in forming balanced rations. A number of foods which are slow of digestion or require much intestinal work should not be combined. Neither should a number of foods which are easily digested and leave but little indigestible residue. Two foods which are either laxative or costive should not be combined. After formulating a ration, it should be critically examined to see if it satisfies the following conditions: (1) Foods economical and suitable to the work to be performed, (2) foods combined so as to secure balanced work of the digestive tract, (3) foods not too laxative or too costive in effect, (4) requisite bulk, (5) sufficient amount of indigestible residue to dilute the waste products in the intestinal tract.

507. Dietary Studies.—A dietary study considers the cost and amount of nutrients consumed by individuals and families. It is an investigation in which men are used and human foods are studied instead of farm animals and animal foods. Dietary studies have shown that frequently money is injudiciously spent in the purchase of high-priced foods which contains but a small amount of nutrients. In a dietary study, the amounts of nutrients in the foods exclusive of the refuse parts are determined. From the weight of the foods, the nutrients contained are calculated using the tables, or they are determined by chemical analysis.

The purchasing of food is frequently done without regard to nutritive value. Erroneous ideas as to the value of foods are often the cause of extravagance in their purchase and use. As for example, it has been claimed that the banana is as valuable as beef, and mushrooms have been erroneously called vegetable beefsteak. Many other foods are assigned fictitious values. Too frequently, choice is made on the basis of palatability, but cost of nutrients and kind of work to be performed should be considered as well as palatability. Dietary studies of the United States Department of Agriculture have shown that lack of knowledge in regard to the value of foods has frequently resulted in whole families being underfed, not from necessity but from lack of judgment in the selection of foods. While it is not practicable or desirable to confine the ration to an absolute standard, dietary studies have shown that for long periods the best results are obtained when foods are combined so as to secure nutrients in approximately the amounts given. By means of a careful study of the dietary, it is possible to reduce the cost of food without impairing its nutritive value, and in many cases, as the cost is decreased, the nutritive value is increased.

508. Chemical Changes in the Cooking of Foods.—The chemical changes which take place in cooking are brought about by the joint action of heat, water and ferments and occasionally by the use of chemicals. The various compounds of which foods are composed, namely, carbohydrates, proteids and fats, are all susceptible to the action of these agencies and the chemical changes which they undergo are briefly discussed in Chapters XXIII and XXIV, treating of the composition of the nitrogenous and non-nitrogenous compounds. Some of the changes are physical rather than chemical in character. All of the different nutrients of foods are influenced by the action of heat.

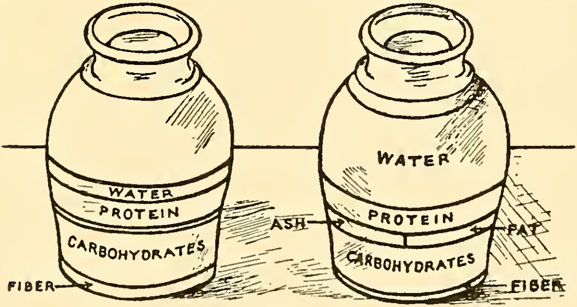

Fig. 101.—Comparative composition of raw and baked beans.

Starch, in the presence of water and heat, undergoes partial hydration, so that the material is in a condition both chemically and mechanically to undergo readily inversion changes. In the cooking and preparation of foods, starch rarely undergoes more than the hydration change. In bread-making, for example, only a small portion of the original starch is converted into soluble forms.

The action of heat upon cellulose and cellular tissue is mechanical rather than chemical. The mass is partially disintegrated and in the case of some of the cellulose, hydration takes place to a limited extent. Human foods, however, contain comparatively little of the cellulose group of compounds. The sugars are partially caromelized by heat, provided it is sufficiently intense, but in ordinary cooking operations, they undergo little or no chemical change unless associated with acids, alkalies or ferment bodies, in which case they may be converted into a number of chemical products.

In the cooking of fruits, as the baking of apples, a portion of the levulose of the fruit-sugar is partially carbonized. In case the fruit is not fully matured, the pectose substances or jellies are converted into a more soluble condition by the action of heat. When heat is sufficiently intense, the essential or volatile oils are expelled.

Fats, as a class, undergo slight oxidation changes by the action of heat. In the process of bread-making, for example, the fat extracted from the bread is different in character from that in the original flour. It is darker in color, and chemical tests show that it is slightly oxidized. Heat causes the proteids to undergo more complex changes than any other class of nutrients. The soluble albumins are coagulated, the globulins also are coagulated, and if the heat is sufficiently intense, molecular changes take place, in which the elements composing the proteid molecule are rearranged in a different way forming, practically, a new molecule with different chemical and physical properties. Since the proteid compounds contain fatty acid radicals, carbohydrate-like bodies, amides and radicals of other compounds, a number of chemical changes may take place, varying with the degree of heat employed.

The chemical changes which take place in the process of cooking influence, to a limited extent, the digestibility of the foods. As a rule, the total digestibility of the carbohydrate nutrients is changed but little by the action of heat. For example, experiments have shown that the carbohydrates in toast are no more completely digested than the carbohydrates in bread, but the action of heat in the preparation of toast produces chemical and physical changes which render the nutrients more susceptible to the action of the digestive fluids, and while toast is no more completely digested than bread, it is more readily acted upon by the digestive fluids. Experiments show that prolonged heat has a tendency to decrease the digestibility of the proteid compounds as a class. In toast, the proteid nutrients are slightly less digestible than in bread.

In general, it can be said that cooking effects ease of digestion rather than completeness of the process, that the carbohydrates are practically as digestible before the action of heat as after and that the proteids are slightly less digestible after the action of prolonged heat. Experiments in the feeding of animals have shown that when foods are cooked, the total digestibility of the nutrients is not increased, and in some cases, a smaller amount of nutrients was absorbed after cooking than before. This does not mean that the cooking of foods is undesirable because ease of digestion is equally as important as completeness of digestion. Also cooking sterilizes the food, which is desirable. Many foods, if consumed uncooked, would be unwholesome because of the presence of ferment bodies or poisonous compounds as ptomains. When acted upon by heat, the ferment bodies are destroyed and the ptomain compounds decomposed.

When salt, soda and other chemicals are used, chemical changes, to a limited extent, take place. Soda, for example, combines with the proteid compounds, forming alkali proteids and the acids form acid proteids. In cooking and preparing foods, many of the physical changes which take place precede and are necessary to the chemical changes. In the boiling of potatoes, for example, heat changes the physical character of the cells but does not alter the solubility of the starch. The albumin is coagulated and small amounts of the mineral compounds and other bodies are extracted. In the cooking of some of the cereals, as oatmeal, if the process is continued for only a few minutes, the starch is not acted upon to any appreciable extent because of the relatively large amount of gelatinous proteids which protect the starch particles. If the cooking is continued for three or four hours, the material is disintegrated, the starch cells are ruptured, and instead of masses of starch, small particles of disintegrated starch may be observed. This starch is partially hydrated. Oatmeal cooked in the two ways, for a few minutes, and for four hours, contains practically the same percentage amount of total starch. In the one case, however, the starch is in large masses, unruptured and unaltered, while in the other, the starch masses have been ruptured, the particles are in a finer state of division and are partially hydrated. Oatmeal which has been cooked for only a few minutes does not readily undergo digestion, but the four hours' cooking produces physical and intermediate chemical changes that cause the starch to yield readily to the action of the diastase ferment.

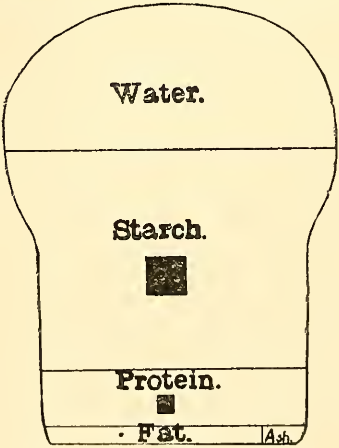

Fig. 102.—Composition of bread.

In the cooking of meats, the heat liquefies a portion of the fat and oxidizes a portion of that which is exposed to the air, while the proteids undergo complex molecular changes. In the cooking and preparation of foods, it should be the object to bring about physical rather than chemical changes. Cooking influences the ease rather than the completeness of digestion.

509. Refuse and Waste Matters.—Nearly all foods contain some refuse material which cannot be consumed as food. In average meat, as purchased in the market, from 7 to 56 per cent. is bone and trimmings. Round steak has least waste while shank has most. Tables showing the average amounts of refuse in meats are given at the close of the chapter. The amount of refuse and waste which a food contains is frequently large enough to make the nutrients of the edible portion quite expensive even in apparently cheap foods. In vegetables, the refuse ranges from 15 to 50 per cent. About 15 per cent. of the weight of potatoes is lost as parings ; of fresh peas, one-half of the weight is pods, and of squash, one-half the weight is rind and seeds. In calculating the nutrients of foods, the refuse and waste parts are to be considered, as there is nearly always a smaller percentage amount of nutrients in the food as purchased than in the edible portion.

510. Loss of Nutrients in the Preparation of Foods.— In the cooking of vegetables, as potatoes, carrots and cabbage, some of the soluble nutrients, as albumin, sugar and mineral matter are extracted and lost in the water. In the case of potatoes, experiments have shown that over 57 per cent. of the total nitrogenous matter is extracted and lost when the potatoes are cut in small pieces and soaked in cold water. When the cleaned, unpeeled potatoes were placed directly into hot water, the losses amounted to only 1 per cent. In the case of carrots and cabbage, the losses are large if the pieces are small and much water is used. The losses from meats incident to cooking need not necessarily be large provided mechanical losses are avoided. In the boiling of meat, there is a decrease in weight of about 30 per cent. due largely to loss of water. About 5 per cent. of proteid matter is extracted, also 13 to 15 per cent. of fat and 51 per cent. of mineral matter. With small pieces of meat, the total loss of weight may be over 50 per cent. The amount of nutrients dissolved varies with the size of the pieces. From experiments made at the University of Illinois, there does not appear to be any great difference in the amount of nutrients extracted from meats by hot or cold water. If the broth is utilized for soup, the nutrients extracted during cooking are not lost.

511. Mineral Matter in a Ration.—In the calculation of human as well as animal rations, the mineral content of the food is not considered along with the other nutrients. This is not because the mineral nutrients are of insignificant value but because nearly all combinations of food contain sufficient, both in amount and variety, for food purposes. Phosphates, compounds of iron, potassium and magnesium are required only in comparatively small amounts. It is estimated that with a man at hard labor from 2 to 3.5 grams per day of phosphoric acid are eliminated through the kidneys. Since this includes all of the soluble mineral phosphates of the food, and not all of those are used for functional purposes, it is not necessary that the food should contain even 2 to 3.5 grams of available phosphates per day. A ration consisting entirely of white bread contains enough phosphates to supply the body and establish a phosphate equilibrium. An average daily ration of mixed foods contains from 5 to 8 grams or more. Meats and nearly all animal foods contain about one per cent. of mineral matter of which about half is phosphoric acid. Milk and eggs contain phosphates and mineral matter in liberal amounts. In a mixed ration of three or more food articles, there is always enough phosphates and mineral matter for purposes of nutrition. A part of the excess of phosphates in a ration is eliminated through the kidneys. The feces also contain phosphoric acid. Inability of the organs to assimilate phosphates, due to malnutrition and lack of available forms of other nutrients, is more frequently a source of trouble than lack of phosphates in the food.

It is estimated that in the ration of an adult, about 20 grams per day of sodium chlorid are necessary. This compound takes an important part in nutrition and is a normal constituent of all the fluids of the body.

512. Digestibility of Foods.—The digestibility of foods is a subject which belongs for investigation alike to the chemist, the physiologist, and the bacteriologist. The physiologist considers the structure of the digestive tract and the functions of the various organs; the chemist studies the chemical changes which occur while the food is undergoing digestion, the completeness of the digestion process, and the extent to which the nutrients of the food are made available to the body; the bacteriologist deals with the ferment bodies which assist in the process of digestion.

513. Digestibility of Meats.—The nutrients of meats, particularly the fats and proteids, are more completely digested than the same classes of nutrients in vegetables. From 93 to 95 per cent. or more of the proteids and fats from foods of animal origin are completely digested, while of vegetables not more than 85 per cent. of the proteids are completely digested except in the case of finely ground flour. Meats are concentrated foods as they furnish large amounts of nutrients in digestible forms. There is less difference in the completeness with which the various meats are digested than in the ease of digestion. Some meats, as pork, veal and mutton, which are called indigestible, are slow of digestion but are quite completely digested. The nutrients of meats can, for all practical purposes, be considered entirely digestible.

514. Digestibility of Vegetable Foods.—Vegetable foods are less completely digestible than animal foods. The larger the amount of cellulose or fiber, the less completely digested is the food. Only a very small amount of the cellulose, even hydrated cellulose, of human foods is available to the body. In many vegetables the nutrients are enclosed in cellular tissue and thus, to a certain extent, are protected from the solvent action of the digestive fluids. The starches and carbohydrates of vegetables are more completely digested than the proteids. Frequently, 95 per cent. of the starch, while only 80 per cent. or less of the proteids, is digested. There is quite a wide range in the digestibility of the nutrients of vegetable foods. The nutrients of fruits are, as a rule, more completely digested than those from other vegetable sources, but fruits contain only comparatively small amounts of nutrients.

515. Relation of Food to Health.—Since the function of food is to supply the body with nourishment, the subjects of food and health are necessarily closely related. If too long continued, either an abnormal or too scant an amount of food affects the health. Not only is the amount important to health but also the quality of the food as nature of nutrients and sanitary condition. Many diseases result from malnutrition, while many others are caused by the use of foods in an unsanitary condition. Food may cause disease either on account of its unsanitary condition or because of an excessive or deficient amount of nutrients, or because of an unbalanced condition of the nutrients.

COMPOSITION OF HUMAN FOODS.

(From Bulletins Nos. 28 and 34, Office of Experiment Stations.)

Kind of food.	Refuse. Per cent.	Water. Per cent.	Nutrients.				Fuel value per pound. Calories.
			Water-free substance. Per cent.	Protein. Per cent.	Fat. Per cent.	Ash. Per cent.	
BEEF—Chuck ribs:							
Edible portion	....	57.3	42.7	17.4	24.4	0.9	1355
As purchased	13.8	49.3	36.9	15.0	21.1	0.8	1170
Loin:							
Edible portion	....	60.5	39.5	18.3	20.2	1.0	1190
As purchased	13.0	52.6	34.4	15.9	17.6	0.9	1040
Neck:							
Edible portion	....	63.4	36.6	19.2	16.5	0.9	1055
As purchased	27.6	45.9	26.5	13.9	11.9	0.7	760
Ribs:							
Edible portion	....	55.4	44.6	16.9	26.8	0.9	1445
As purchased	20.8	43.8	35.4	13.4	21.3	0.7	1150
Round:							
Edible portion	....	65.8	34.2	19.7	13.5	1.0	935
As purchased	7.7	60.7	31.6	18.1	12.6	0.9	870
Rump:							
Edible portion	....	56.7	43.3	16.8	25.6	0.9	1395
As purchased	21.4	44.5	34.1	13.2	20.2	0.7	1095
Shank, fore:							
Edible portion	....	67.9	32.1	19.6	11.6	0.9	855
As purchased	36.9	42.9	20.2	12.3	7.3	0.6	535
Shank, hind:							
Edible portion	....	67.8	32.2	19.8	11.5	0.9	855
As purchased	53.9	31.3	14.8	9.1	5.3	0.4	395
Fore quarter:							
Edible portion	....	61.4	38.6	17.5	20.2	0.9	1180
As purchased	19.4	49.5	31.1	14.1	16.3	0.7	950
Hind quarter:							
Edible portion	....	61.0	39.0	18.0	20.1	0.9	1185
As purchased	15.8	51.3	32.9	15.2	17.0	0.7	1000
Cooked, corn'd & can'd:							
As purchased	....	53.1	46.9	28.5	14.0	4.4	1120
Dried and smoked:							
As purchased	....	50.8	49.2	31.8	6.8	..	845

COMPOSITION OF HUMAN FOODS—(*Continued*).

Kind of food.	Refuse. Per cent.	Water. Per cent.	Nutrients.				Fuel value per pound. Calories.
			Water-free substance. Per cent.	Protein. Per cent.	Fat. Per cent.	Ash. Per cent.	
VEAL—Leg, whole:							
Edible portion	....	70.4	29.6	20.1	8.4	1.1	730
As purchased	15.6	59.4	25.0	16.9	7.2	0.9	620
Rump:							
Edible portion	....	62.6	37.4	20.1	16.2	1.1	1055
As purchased	30.2	43.7	26.1	14.0	11.3	0.8	735
Fore quarter:							
Edible portion	....	71.7	28.3	19.4	8.0	0.9	700
As purchased	24.5	54.2	21.3	14.6	6.0	0.7	525
Hind quarter:							
Edible portion	....	70.9	29.1	19.8	8.3	1.0	720
As purchased	20.7	56.2	23.1	15.7	6.6	0.8	570
LAMB—Leg, hind:							
Edible portion	....	63.9	36.1	18.5	16.5	1.1	1040
As purchased	17.4	52.9	29.7	15.2	13.6	0.9	855
Loin:							
Edible portion	....	53.1	46.9	17.6	28.3	1.0	1520
As purchased	14.8	45.3	39.9	15.0	24.1	0.8	1295
Neck:							
Edible portion	....	56.7	43.3	17.5	24.8	1.0	1375
As purchased	17.7	46.7	35.6	14.4	20.4	0.8	1130
Shoulder:							
Edible portion	....	51.8	48.2	17.5	29.7	1.0	1580
As purchased	20.3	41.3	38.4	14.0	23.6	0.8	1255
MUTTON—Leg, hind:							
Edible portion	....	62.8	37.2	18.2	18.0	1.0	1100
As purchased	18.0	51.4	30.6	14.9	14.9	0.8	905
Loin:							
Edible portion	....	50.1	49.9	15.9	33.2	0.8	1695
As purchased	15.3	42.2	42.5	13.2	28.6	0.7	1450
Neck:							
Edible portion	....	58.2	41.8	16.3	24.5	1.0	1335
As purchased	28.4	41.6	30.0	11.7	17.6	0.7	960
Shoulder:							
Edible portion	....	61.9	38.1	17.3	19.9	0.9	1160
As purchased	21.7	48.5	29.8	13.5	15.6	0.7	910

COMPOSITION OF HUMAN FOODS—(*Continued*).

Kind of food.	Refuse. Per cent.	Water. Per cent.	Nutrients.				Fuel value per pound. Calories.
			Water-free substance. Per cent.	Protein. Per cent.	Fat. Per cent.	Ash. Per cent.	
MUTTON—(Contin'd). Fore quarter:							
Edible portion	....	51.7	48.3	15.0	32.4	0.9	1645
As purchased	21.1	40.6	38.3	11.9	25.7	0.7	1305
Hind quarter:							
Edible portion		54.8	45.2	16.2	28.2	0.8	1490
As purchased	16.7	45.6	37.7	13.5	23.5	0.7	1245
Side, without tallow:							
Edible portion	....	53.1	46.9	15.4	30.7	0.7	1580
As purchased	19.2	42.9	37.9	12.5	24.7	0.7	1275
PORK—Flank:							
Edible portion	....	59.0	41.0	17.8	22.2	1.0	1265
As purchased	71.2	17.0	11.8	5.1	6.4	0.3	365
Ham, smoked:							
Edible portion	....	40.7	59.3	15.5	39.1	4.7	1940
As purchased	14.4	34.9	50.7	13.3	33.4	4.0	1655
Shoulder, fresh:							
Edible portion	....	57.5	42.5	15.6	26.1	0.8	1390
As purchased	46.6	30.4	23.0	8.3	14.3	0.4	760
Salt, clear fat:							
As purchased	....	7.3	92.7	1.8	87.2	3.7	3715
Salt, lean ends:							
Edible portion	....	19.9	80.1	7.3	67.1	5.7	2965
As purchased	11.2	17.6	71.2	6.5	59.6	5.1	2635
Bacon, smoked:							
Edible portion	....	18.2	81.8	10.0	67.2	4.6	3020
As purchased	8.0	16.8	75.2	9.2	61.8	4.2	2780
Side:							
Edible portion	....	29.4	70.6	8.5	61.7	0.4	2760
As purchased	11.2	26.1	62.7	7.5	54.8	0.4	2455
POULTRY—Chicken:							
Edible portion	....	74.2	25.8	22.8	1.8	1.2	500
As purchased	34.8	48.5	16.7	14.8	1.1	0.8	325
Turkey:							
Edible portion	....	55.5	44.5	20.6	22.9	1.0	1350
As purchased	22.7	42.4	34.9	15.7	18.4	0.8	1070

COMPOSITION OF HUMAN FOODS—(*Continued*).

Kind of food.	Refuse. Per cent.	Water. Per cent.	Nutrients.				Fuel value per pound. Calories.
			Water-free substance. Per cent.	Protein. Per cent.	Fat. Per cent.	Ash. Per cent.	
FISH, fresh—Cod, dried:							
Edible portion	....	82.6	17.4	15.8	0.4	1.2	310
As purchased	29.9	58.5	11.6	10.6	0.2	0.8	205
Mackerel, entrails rem'd:							
Edible portion	....	73.4	26.6	18.2	7.1	1.3	640
As purchased	40.7	43.7	15.6	11.4	3.5	0.7	360
Salmon, Cal., sections:							
Edible portion	....	63.6	36.4	17.5	17.9	1.0	1080
As purchased	10.3	57.9	31.8	16.1	14.8	0.9	925
Salmon trout, whole:							
Edible portion	....	69.1	30.9	18.2	11.4	1.3	820
As purchased	56.3	30.0	13.7	7.7	5.4	0.6	985
Trout, brook, whole:							
Edible portion	....	77.8	22.2	18.9	2.1	1.2	440
As purchased	48.1	40.4	11.5	9.8	1.1	0.6	230
FISH, pres'd, cod, salt:							
Edible portion	....	53.6	46.4	21.4	0.4	24.6	410
As purchased	24.9	40.3	34.8	16.0	0.4	18.4	315
Mackerel, salt:							
Edible portion	....	42.2	57.8	22.0	22.6	13.2	1360
As purchased	22.9	32.5	44.6	17.0	17.4	10.2	1050
Salmon, canned, as purc'd	....	64.5	35.5	20.1	11.6	2.4	890
Sardines, can'd, as purc'd	....	56.4	43.6	25.3	12.7	5.6	1010
Shell fish, clams, round:							
Edible portion	....	86.2	13.8	6.5	0.4	2.7	215
As purchased	67.5	28.0	4.5	2.1	0.1	0.9	65
Oysters, "solids," as pur'd	....	88.3	11.7	6.1	1.4	0.9	235
DAIRY PRODUCTS:							
Cheese—Cheddar	....	33.00	67.00	28.00	35.00	4.0	1999
Butter	....	13.00	87.00	0.50	85.00	1.5	3600
*Milk	....	87.00	13.00	3.5	4.00	0.7	323
*Cream	....	......	......	2.5	20.0	0.5	....
EGGS:							
In shell	13.7	63.1	23.2	12.1	10.2	0.9	655
Edible portion	....	73.8	26.2	14.9	10.5	0.8	721

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* Milk also contains 4.8 per cent. carbohydrates. The fat content of cream ranges from 10 to 30 per cent.

COMPOSITION OF HUMAN FOODS—(*Continued*).

Kind of food.	Refuse. Per cent.	Water. Per cent.	Protein. Per cent.	Fat. Per cent.	Carbohydrates. Per cent.	Ash. Per cent.	Fuel value per pound. Calories
Wheat flours, meals, etc.							
*Roller process flour....	....	11.9	12.6	0.8	74.3	0.4	1650
Spring wheat flour......	....	11.6	11.8	1.1	75.0	0.5	1660
Winter wheat flour......	....	12.5	10.4	1.0	75.6	0.5	1640
Buckwheat flour........	....	14.3	6.1	1.0	77.2	1.4	1590
Cornmeal, bolted	....	12.9	8.9	2.2	75.1	0.9	1655
Oatmeal	....	7.2	15.6	7.3	68.0	1.9	1860
Rice	....	12.4	7.8	0.4	79.0	0.4	1630
Rice, boiled.............	....	52.7	5.0	0.1	41.9	0.3	875
*White bread...........	....	31.0	9.9	1.4	57.1	0.5	1306
*Graham bread..........	....	32.2	9.5	2.5	54.7	1.1	....
Crackers	....	8.2	10.7	9.9	68.8	2.4	1895
Sugar, granulated.......	....	....	....	..	98.0	..	1600
Sugar, maple	....	....	....	..	82.8	..	1540
Vegetables—Asparagus:							
As purchased	....	94.0	1.8	0.2	3.3	0.7	105
Beans, dried.							
As purchased	....	13.2	22.3	1.8	59.1	3.6	1590
Beets:							
Edible portion	....	87.6	1.6	0.1	9.6	1.1	210
As purchased	20.0	70.0	1.3	0.1	7.7	0.9	170
Cabbage:							
Edible portion	....	90.3	2.1	0.4	5.8	1.4	165
As purchased	15.0	76.8	1.8	0.3	4.9	1.2	140
Carrots:							
Edible portion	....	88.2	1.1	0.4	9.2	1.1	210
As purchased	20.0	70.5	0.9	0.3	7.4	0.9	170
Parsnips:							
Edible portion	....	79.9	1.7	0.6	16.1	1.7	355
As purchased	20.0	63.9	1.3	0.5	12.9	1.4	285
Peas, dried:							
As purchased	...	10.8	24.1	1.1	61.5	2.5	1640
Peas, green:							
Edible portion..........	....	78.1	4.4	0.5	16.1	0.9	400
As purchased	50.0	39.0	2.2	0.3	8.0	0.5	200

* From Minnesota analyses.

COMPOSITION OF HUMAN FOODS—(*Continued*).

Kind of food.	Refuse. Per cent.	Water. Per cent.	Protein. Per cent.	Fat. Per cent.	Carbohydrates. Per cent.	Ash. Per cent.	Fuel value per pound. Calories.
Potatoes, raw:							
Edible portion	....	78.9	2.1	0.1	18.0	0.9	380
As purchased	15.0	67.1	1.8	0.1	15.3	0.7	325
Potatoes, sweet:							
Edible portion	....	69.3	1.8	0.7	27.1	1.1	565
As purchased	15.0	58.9	1.5	0.6	23.1	0.9	480
Squash:							
Edible portion	....	86.5	1.6	0.6	10.4	0.9	245
As purchased	50.0	43.3	0.8	0.3	5.2	0.4	125
Turnips:							
Edible portion	....	88.9	1.4	0.2	8.7	0.8	195
As purchased	30.0	62.2	1.0	0.1	6.1	0.6	135
Tomatoes:							
Edible portion	....	96.0	0.8	0.4	2.5	0.3	80
Green corn	....	81.3	2.8	1.1	14.1	0.7	360
Cucumber	....	96.0	0.8	0.2	2.5	0.5	70
Spinach	....	92.4	2.1	0.5	3.1	1.9	120
Sauer kraut	....	86.3	1.5	0.8	4.4	7.0	145

INDEX

Acid, citric ... 207
  hydrochloric ... 80–82
  malic ... 206
  oxalic ... 206
  phosphoric ... 94
  salts ... 75
  sulfuric ... 99
  tannic ... 207
  tartaric ... 206
Acids ... 37, 72
  basicity of ... 76
  fatty ... 199, 201
  naming of ... 74
  organic ... 205
Aerobic ferments ... 319
Air ... 66–71
  a mechanical mixture ... 66
  ammonium compounds of ... 68
  as plant food ... 71
  carbon dioxid of ... 66, 68
  impurities in ... 70
  moisture in ... 69
Albumin in meat ... 370
Albumins ... 218
Albuminates ... 220
Albuminoids ... 226–228
  food value of ... 227
Alfalfa ... 267
Aliphatic series ... 114
Alkaloids ... 231
Allotropism ... 48
Aluminum ... 145
  in plants ... 168
Alums ... 146
Amides ... 228–231
  food value ... 230
  occurrence in animals ... 229
    plants ... 229
Ammonia ... 88
Ammonia, properties of ... 89
  uses of ... 90
Ammonium compounds in air ... 68
Anaerobic ferments ... 319
Anhydrids ... 91
Animal bodies, composition of ... 366–369
  fat in ... 367
  mineral matter in ... 366
  nitrogenous matter of ... 368
Animal life, chemical change ... 2
Apatite ... 93
Apparatus, names of ... 19–21
Apples ... 134
Argon ... 70
Aromatic series ... 114
Arsenic, occurrence ... 152
  poisoning ... 153
Ash determination ... 160
Ash elements, essential ... 162
  of animal bodies ... 366
  of plants ... 159–174
    composition of ... 173
Atomic weight ... 13
  table of ... 11
Atoms ... 4

Bacteria, disease-producing ... 323
Balanced rations ... 344
  calculation of ... 355
Barley ... 297, 302
  grading of ... 301
Bases ... 72
  naming of ... 74
Beans ... 299
Beef production, foods for ... 348–351
Benzine ... 113

- Bessemer process 142
- Blast-furnace 141
- Bleaching powder 136
- Bordeaux mixture 149
- Brick 147
- Bromus Inermis 265
- Buckwheat 298
- Burette 77

- Calcium 134
  - carbonate 134
  - chlorid 136
  - compounds 134–139
  - hydroxid 135
  - hypochlorite 136
  - in plants 168
  - oxid 135
  - phosphate 136
  - sulfate 136
- Caloric value of rations 358
- Calorie 184, 327
- Calorimeter 327–331
- Candle, chemistry of 52–54
  - power 112
- Capillarity of plant tissue 241
- Carbids 115
- Carbohydrates 176–196
  - digestibility of 333
- Carbon 46–55
  - a reducing agent 48
  - compounds 54
  - a decolorizer 52
    - deodorizer 52
  - dioxid 107
    - in air 66–68
    - test for 135
  - disulfid 114
  - monoxid 108
  - occurrence 46
  - oxids of 107
  - preparation of 46
  - properties of 47
  - rôle in plant and animal life 54–55
- Carbonates 107
- Carrots 313
- Cellulose 177–181
  - chemical properties of 178
  - food value of 179
  - function of 178
  - physical properties of 177
- Chemical affinity 5
  - analysis 6
  - changes 2
  - properties defined 9–10
- Chemistry 2
- Chlorids 85
- Chlorin 82
  - family 84
  - preparation 83
  - properties 84
- Chlorophyl 242–246
  - function of 245
  - production 243
- Clay 105
- Cleaning apparatus 28–29
- Climate and plant growth 260
- Clover, composition of 250
  - early and late cut 249
  - hay 266, 271
  - rapidity of growth 248
- Coal 48
- Combination of elements 12, 16, 17
- Combustion 49
  - products of 53
  - spontaneous 51
- Composition of matter 1–7
- Compounds 5
- Cooking of foods, changes during
  - carbohydrates 384
  - fats 385
  - proteids 385
  - losses during 388
- Copper 148
  - compounds 148–149
  - sulfate 148
- Corks, perforation of 22
- Corn (see maize).
  - flour 294
  - fodder 268

- Cottonseed cake and meal 308
- Creosote 113
- Crop growth and soils 258
- Crops, improvement of 262
- Crude fiber 179
  - protein 224
- Crystallization, water of 58

- Dairy cows, food for 352
  - requirements of 351
- Definite proportion, law of 15
- Dextrin 186
- Dextrose 190
  - chemical and physical properties of 191
- Dialysis 104
- Dietary standards 374
  - studies 382
- Digestible nutrients 341
  - in fodders and grains ... 363–365
- Digestion, a bio-chemical process 325
  - chemistry of ... 325–344
  - coefficients 339
    - not constant 339
  - experiments 325
  - factors influencing . 334
- Digestibility, factors influencing 379–381
  - influence of cooking upon 338, 385
- Disease, air 70
  - and water supply 59–60
- Double salts 75
- Dry matter 157

- Elastin 227
- Elements and compounds, properties 8–18
  - classification of 72
  - combination of . 12, 16, 17
  - cycle of 119
- Energy, available, of foods 331
- Energy, net, of foods 332
- Epsom salt 138
- Equations 120–126
  - for classroom ... 124–126
- Essential oils 208–211
  - food value 210
  - synthetic production of 210
- Ether extract 203–204

- Fat in animal bodies 367
- Fats 197–205
  - amounts of, in foods 203
  - chemical properties 198
  - digestion of 334
  - food value of 201
  - formation in plants 197
  - heat from 201
  - physical properties 198
- Feeding of animals 344–356
  - and sanitary conditions 361
  - standards 362
  - stuffs, inspection of ... 310
- Feldspar 105
- Fermentation 318–324
  - conditions necessary for 320
- Ferments, aerobic 319
  - anaerobic 319
  - and bread-making .. 321
  - in butter- and cheese-making 321
  - disease-producing .. 323
  - and food digestion .. 322
    - preservation 322
  - in seeds 320
    - soils 320
  - insoluble 318
  - soluble 318
- Fertilizers, phosphate 94
- Fiber, crude 179
- Filter-paper, folding of 26
- Flame, structure of 52
- Flax, rapidity of growth 251
- Flaxseed, grading of 301

Fodders, composition of 263–272
  cutting of 260
Foods, caloric value of 327
  combination and digestibility of 336
  cost and value of 359
  factors influencing digestibility 379–381
  influence of cooking upon digestibility 338
  mechanical condition of, and digestion 335
  palatability of 337
  refuse and waste matters of 387
Food, relation of, to health 392
  requirements of animals 345
  supply and stage of growth 346
Formula 12
Formulas, structural 186
Fruits 314–316
  dried 316
  food value 317
Fuels 115

Galvanized iron 150
Gasoline, use of 110
Gelatin 227, 372
Germination of seeds 237–239
  conditions necessary for 239
Glass 138
  tubing, bending 22
    cutting 21
Gliadin 275
Globulins 219
Glucose, test for 149
Gluten 277
  meal 309
Glutenin 275
Grains, composition of 302
  cost and value of 359
  grading of 299
Grapes 315
Grass, pasture 268
Gypsum 136

Helium 70
Hemoglobin 371
Horses, foods for 348
  food requirements of 347
Human and animal feeding compared 374
  body, composition of 373
  food problems 379
  foods, composition of 393–398
    cost and value of 377
  rations 376
    calculation of 376
    requisites of 381
Hydrated cellulose 178
Hydrocarbons 109
Hydrochloric acid 80–82
  preparation 80
  properties 82
Hydrogen 37–41
  importance 41
  occurrence 37
  preparation 37–38
  properties 39
  peroxid 70
  sulfid 102
Hydroxyl 72, 74

Illuminating gas 111
Indestructibility of matter 3
Insecticides 152
Insoluble proteids 222
Invert sugars 189
Iron 140
  compounds 140–144
Iron, galvanized 150
  in plants 168
  ores, reduction 140
  rusting of 144
  wrought 142

Keratin 371

Kerosene oil, testing of 110

Laboratory manipulation 19–30
  practice, importance . 19
Lactose 189
Law of definite proportion 15
  multiple proportion 91
Lead 150
  carbonates 151
  compounds 150, 151
  oxids 150
  uses of 151
Lecithin 234
Lemons 314
Levulose 192
Ligno-cellulose 178
Lime kiln 134
Lime, slaking of 137
Limestone 134
Linseed meal 307

Magnesium, occurrence 138
  in plants 167
  salts 138
Maintenance ration 344
Maize as food 294
  as forage 252
  composition of 252–256
    kernel 289
  grading of 293
  husk 255
  leaves 254
  nitrogenous and non-nitrogenous 291
  products 294
  proteids of 290
  roots 252
  stalk 253
  structure of kernel 289
  varieties of 293
Malt sprouts 309
Maltose 189
Mangels 313
Marsh gas 109
Matter, indestructibility of 3
Measuring liquids 24
Meats, albumin of 370
  albuminoids of 372
  composition of 393–396
  digestibility of 390
  proteids of 370
Mechanical mixtures 6
Mercury 153
  compounds 153
Metric equivalents 23
Mica 105
Milk solids 158
  sugar 189
Mill and by-products 303–311
Millet 299
Mineral food, assimilation of, by plants 247
  matter of crops ... 159–174
  oils 112
  in a ration 389
Minium 151
Molecules 3
Molecular weights 11–14
Mortar 137
Mucin 227
Multiple proportion, law of 91
Myosin 370

Naming of acids 74
  bases 74
  salts 75, 76
Neutralization 72, 76
Nitrates 86
Nitric acid 86-88
  importance 88
  preparation 86
  properties 88
Nitrogen 42–46
  assimilation of, by plants, ... 247
  compounds, importance of. 45, 92
  determination of 225
Nitrogen-free extract 196
Nitrogen, occurrence 42

Nitrogen, oxids of 90
  preparation 42–43
  properties 44
  rôle in plant and animal life 45
Nitrogenous compounds 214–235
  matter, animal bodies 368
Non-nitrogenous compounds, food value 213
Non-nitrogenous compounds, general relationship 212
Note-book, laboratory 27
Nuclein 226
Nutrients, digestible, of foods 341
Nutrition 325–366
Nutritive ratio 357

Oat feed 308
  hay 265
Oats, composition of 296
  as food 297
  grading of 300
  structure of kernel 296
Olein 200
Olives 316
Oranges 314
Organic compounds in plants 117
  matter 175
    decay of 118
    production of 245
Osmosis 241
Oxidation 35
Oxids 34
Oxygen 31–37
  importance 35
  occurrence 31
  preparation 31
  properties 34
Ozone 70

Palmitin 199
Paris green 153
Parsnips 313
Pectin bodies 196
Pentosans 195
Peptic ferments 322, 333
Peptones 221
Petroleum 109
Phosphates 94
  fertilizers 94
  in human foods 389
Phosphoric acid 94
Phosphorus 93
  compounds 95
  importance 95
  oxids 93
  in plants 169
  properties 93
Physical change 2
  properties defined 8–18
Physics 2
Pigs (see swine).
Plant ash 155–174
  growth 235–246
  juices, movement of 240
  life, chemical change 2
    physical change 2
Plaster of Paris 136
Plumbing 29
Polariscope 193
Porcelain 147
Potassium 127
  carbonate 129
  chlorate 129
  compounds 127–130
  hydroxid 127
  nitrate 128
  in plants 164
  sulfate 129
Potatoes 312
Pottery 147
Prairie hay 265
Properties, chemical 9–10
  of elements and compounds 8–18
  physical 8–9
Proportion, law of definite 15
Protein, crude 224
Proteids 215

Proteids, amount in plants.....224
  chemical properties ..217
  classification.........218
  digestibility of.......333
  food value...........223
  insoluble 222
  of meat..............370
  physical properties...216
  of wheat.............274
Proteoses 221
Protoplasm 243

Quartz 103

Radicals......................73
  naming of.............74
Rape 267
Rational feeding of animals.344–366
  men....374–398
Rations, balanced 344
  caloric value of.......358
  maintenance 344
  standard 345
Reactions 120–126
  illustrated 121, 122
  impossible 123
Reagent bottles, handling of....25
Reduction 48
Rice 298
Roots...................312, 313
Rye....................298, 302
  grading of................300

Salts 75
  acid 75
  double....................75
  naming of............75, 76
Sand culture..................164
Sanitary conditions and feeding
 361
Saponification 200
Seeds 235–239
  ash of...................235
  and crop growth.........257
  nitrogenous compounds of 236
Sheep, food requirements of ...354
Silage 269
Silica 103
Silicates 105
Silicic acid..................103
Silicon 103
  compounds, importance
    of 105
Silo, losses in...............270
Sodium........................129
  carbonate 131
  chlorid.................130
  hydroxid............. 132
  nitrate 131
  phosphate.............132
  in plants 168
  salts 130–133
Soils 105
Spontaneous combustion 51
Starch....................181–186
  chemical properties 181
  food value..............184
  function 183
  physical properties......182
  in seeds 237
Stearin 199
Steel 142
Steer feeding 348–351
Stover........................268
Straw 263
Strawberries 315
Sucrose.......................188
  chemical properties 188
  physical properties.....188
Sugar 187–195
  beets 194
Sulfates 101
Sulfids 101
Sulfur.........................97
  dioxid....................98
  preparation 97
  properties 97
  uses 98
  in plants 170
Sulfuric acid...................99

Sulfuric acid properties........100
Swine, food requirements of....353
Symbols........................10
Syntonin......................370

Timothy hay.............264, 274
Tin...........................150
  salts.......................150
Tubing, glass, bending.........22
  cutting......................21
Turpentine....................113
Typhoid bacillus...............59
Trypsin.......................333

Valence........................15
  table of.....................11
Vegetable foods.........397–398
  digestibility of............391
Ventilation of rooms........67–69

Water.......................56–65
  borne diseases...............59
  contamination of.........61, 62
  culture.....................163
  of crystallization...........58
  distillation of..............57
  electrolysis.................56
  filters..................63, 64
  mineral matter of............61
  natural......................59
  organic matter in............60
  oven........................155
  physical properties..........57
  in plants..............155, 157
  purification of..........64, 65
Waxes.........................201
Weighing.................23, 160
Weights, atomic..........11, 13
  molecular....................14
Wheat.....................273–388
  American and foreign........288
  as animal food..............286
  as human food...............287
  bran........................304
  bread-making properties of..277
  by-products.................303
  composition of varieties....285
  flour, grades of............303
  germ........................306
  gluten of...................277
  grading of..................283
  influence of climate upon...281
    fertilizers upon..........279
  middlings...................305
  nitrogen content of, and flour...278
  proteids of.................274
  rapidity of growth..........247
  screenings..................307
  shorts......................306
  storage of..................282
  structure of kernel.........273
  unsound.....................284
  variations in composition...279
White lead....................151

Zeolites......................105
Zinc compounds................149
  occurrence..................149

CORRECTIONS

Page 23, in last line, read "SO_4," not "SO_2."
Page 94, line 21, read "$H_4P_2O_7$," not "$H_2P_2O_7$."
Page 125, Equation 40, read "3KOH."
Page 132, line 18, read "Na_2HPO_4."

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